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ANNOUNCEMENT

The serial publications of the Roosevelt Wild Life Forest Experiment Station consist of the following:

1. **Roosevelt Wild Life Bulletin.**
2. **Roosevelt Wild Life Annals.**

The *Bulletin* is intended to include papers of general and popular interest on the various phases of forest wild life, and the *Annals* those of a more technical nature or having a less widespread interest.

These publications are edited in cooperation with the College Committee on Publications.

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Dr. Charles C. Adams,
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THE RELATION OF FORESTS AND FORESTRY TO HUMAN WELFARE

"Forests are more than trees. They are rather land areas on which are associated various forms of plant and animal life. The forester must deal with all. Wild life is as essentially and legitimately a part of his care as are water, wood and forage. Forest administration should be planned with a view to realizing all possible benefits from the land areas handled. It should take account of their indirect value for recreation and health as well as their value for the production of salable material; and of their value for the production of meat, hides and furs of all kinds as well as for the production of wood and the protection of water supplies.

"Unquestionably the working out of a program of wild life protection which will give due weight to all the interests affected is a delicate task. It is impossible to harmonize the differences between the economic, the æsthetic, the sporting and the commercial viewpoints. Nevertheless, the practical difficulties are not so great as they appear on the surface."

HENRY S. GRAVES,
Former Chief Forester, U. S. Forest Service.
Recreation, Vol. 52, p. 236; 1915.

"Outdoor recreation is a necessity of civilized life, and as civilization becomes more intensive the demand grows keener. The vast extent of our present National Forests, their enticing wildness, and the notable beauty of the native landscape lure men and women thither by hundreds of thousands. The really enormous extent and value of this kind of forest product has been generally overlooked in America. This oversight, however, is only local and temporary. In older countries, where public forests have existed for centuries, the recreation use of such areas has always been recognized. It would be perfectly easy to show that recreation was, in fact, the original and primary purpose in the creation of public forests.

"The moment that recreation (using this word in a very liberal meaning) is recognized as a legitimate Forest utility the way is opened for a more intelligent administration of the National Forests. Recreation then takes its proper place along with all other utilities. In each particular case these utilities are weighed against one another and a plan of administration devised to adjust and harmonize, to the utmost point practicable, the various forms of use so that the largest net total of public good may be secured. Where one must be subordinated to another, preference is given to that of highest value to the public."

FRANK A. WAUGH,
Collaborator, U. S. Forest Service.
Recreation Uses on the National Forests, pp. 3-4, 5; 1918.

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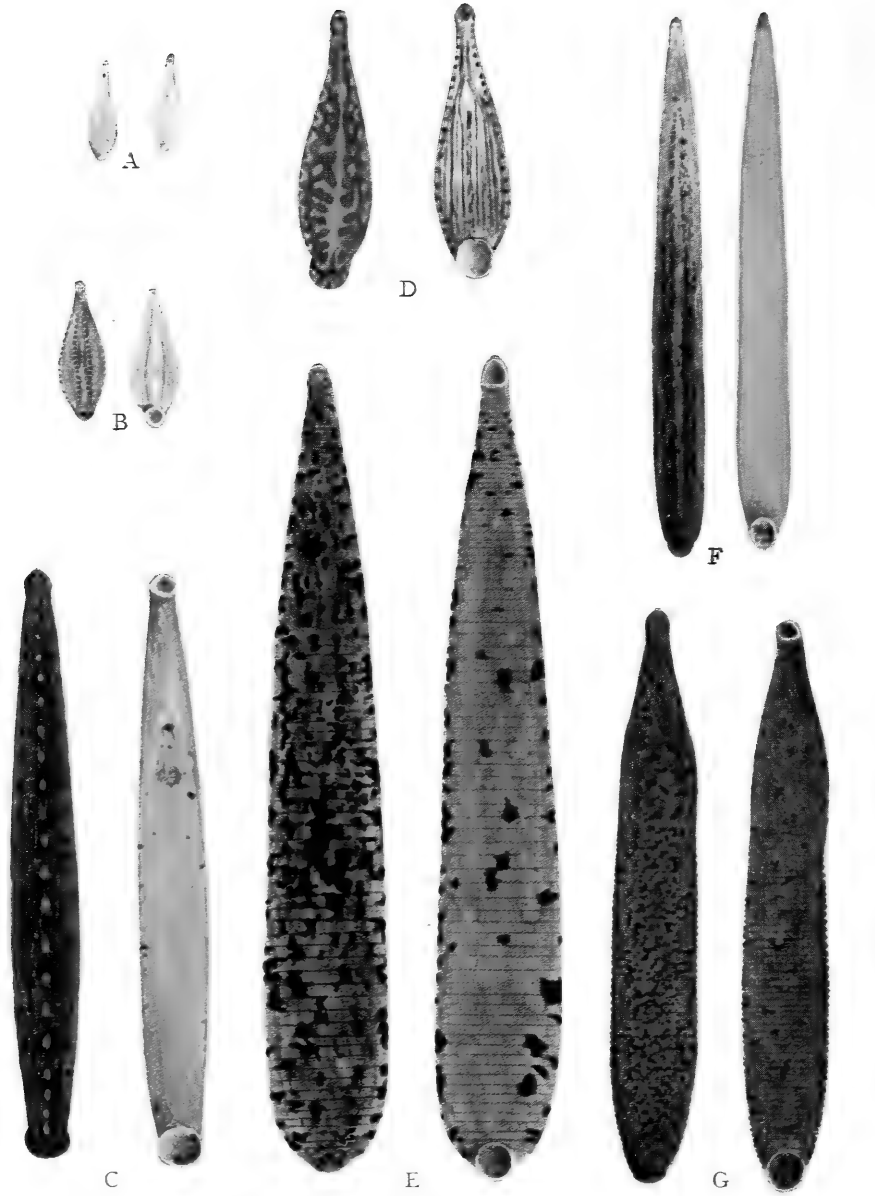

Plate 1. Leeches of the Palisades Interstate Park

Dorsal (left) and ventral (right) views of each species of leech

A. Helobdella stagnalis
B. Glossiphonia complanata
C. Macrobdella decora
D. Placobdella parasitica
E. Haemopis grandis
F. Erpobdella punctata
G. Haemopis marmoratis

THE CONTROL OF BLOOD-SUCKING LEECHES, WITH AN ACCOUNT OF THE LEECHES OF PALISADES INTERSTATE PARK

By Dr. J. Percy Moore
Professor of Zoology, University of Pennsylvania

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INTRODUCTION

In the spring of 1919 Dr. Charles C. Adams, of the New York State College of Forestry, acting on behalf of the Commissioners of Palisades Interstate Park, consulted me concerning the possibility of exterminating or repressing the blood-sucking leeches that infested certain of the lakes and ponds in the Park to the annoyance and alarm of bathers. I was engaged, at that time, under the auspices of the United States Bureau of Fisheries, in continuing a study of the control of mosquitoes by natural biological agencies in the fresh waters of the northern States which had been begun the previous summer as a piece of war work. A cooperative plan was therefore arranged between the Bureau of Fisheries, the College of Forestry and the Park Commissioners, by which work on the two problems could be conducted simultaneously. Accordingly I spent most of July and August of 1919 in field work at the Harriman section of the Palisades Interstate Park. Headquarters in the Park were established at the Guest House on Little Long Pond (Upper Kanahwauke Lake) where excellent living accommodations and field laboratory facilities were provided by the Commissioners. After a preliminary examination in company with Dr. Adams, Carr Pond was selected as the most favorable place for investigation and experiment, although visits were made to many other bodies of water within the Park. The results of the cooperative investigations on the control of mosquitoes by fishes within the Palisades Interstate Park have been published in " Use of Fishes for Control of Mosquitoes in Northern Fresh Waters of the United States." (Ann. Rep. U. S. Bur. Fisheries for 1922. Appendix IV., pp. 1–60. Document No. 923.) It is a pleasure to acknowledge the numerous courtesies received from Dr. Charles C. Adams, Mr. Edward F. Brown, Superintendent of Camp Activities, and Major William A. Welch, Chief Engineer and General Manager of the Park; and the invaluable services of my assistant, Mr. Robert K. Fletcher, especially during the latter part of the season.

DESCRIPTION OF CARR POND AND THE LEECH PROBLEM

Carr Pond (Lake Stahahe) is an irregular hatchet-shaped body of water about a mile long and nearly half as wide, having an area of sixty acres (figures 1 and 2). It is situated on the main park road (Seven Mile Drive) about two miles from the Guest House and one and one-quarter miles from Southfields on the Erie Railway. Its long axis inclines about 30° east of north. The present dimensions of the lake have been attained by the erection of a concrete dam across a narrow steep-sided valley, thus backing up and retaining the overflow from the original pond, which was a small body of water of about twelve acres area, in the midst of a bog now covered by the large end of the lake. A temporary dam had first been constructed farther up the valley just below Kennedy House Camp, impounding an area of more than forty-five acres which is referred to as the old part of the lake, the lower extension being the new part. The outline map (figure 3) shows these features. At the enlarged southwestern end several rocky points jut out, and here also are three small, rocky wooded islets (figure 1). The banks are in part steep and rocky and in part shelving and earthy. At the southern end are two shallow protected coves or basins in which the depth over a considerable area seldom exceeds four feet (figures 5 and 6). These shallows appear to have been formed by flood deposits by the brook which flowed through them on its course to the original pond. Around the body of the lake are other shallow bays and indentations (figures 7, 8 and 10). These are rich in aquatic and emergent vegetation. Into the larger of the coves empty a small brook and several springs, and additional small springs add their flow into other parts of the lake, whose water, however, consists chiefly of melted snow from the surrounding hills impounded during the spring thaws.

The lake bottom may be roughly divided into two parts. One covers an erea of several acres, representing the original bog pond near the middle of the large end (figure 3). It is a soft ooze of acid reaction, rich in slowly decaying organic matter and contains little animal life except red chironomid larvae, which are plentiful. This is the deepest part of the lake, the soundings varying from twenty-one to thirty feet; it also has the lowest bottom temperature, registering 60°F. on July 23 when the surface temperature was 78°F. The remainder is chiefly the flooded forest floor consisting of peaty turf with the stumps of felled trees, etc. In some places considerable areas of matted fibrous roots become detached, and buoyed up by the water rose to the surface as floating islands (figure 7), leaving the underlying soil exposed. Soft muddy bottoms filled with decaying organic matter are found in the shallow coves and flooded bogs.

The temperature of the shallower parts of the lake down to ten feet ranged from 72° to 74°F., being from 2° to 6° below the surface temperature. The flooded boggy area at the original pond site had a lower bottom temperature ranging from 60° to 68°, the lowest temperature being within the limits of the original pond and doubtless due to the springs common there.

Around the shores of Carr Pond are scattered the camps, numbering fourteen during the summer of 1919. The older camps are mostly situated on the eastern shore of the body of the lake, while the newer ones line both sides of the narrow handle-like extension completed in 1918. These camps are occupied for the most part by hundreds of children of both sexes brought from New York City and Brooklyn by various welfare organizations. Naturally a favorite pastime is bathing (figure 9), and an important part of the discipline consists in instruction in swimming. Most of the camps are provided with swimming docks (figure 11), and those occupied by younger children with safety cribs or stages built of wood weighted and held in place by piles of broken stone. The report has been that bathers were attacked and bitten by the leeches, thereby causing much alarm among the more timid, some of whom refused to subject themselves to a repetition of the experience. Complaint among the camp directors had become so general that the lake had gained a bad reputation. As a means of estimating the importance of the problem all of the camp directors were interviewed immediately after my arrival. As a result several points became clear. No cases of actual serious injury were reported. One case was described of a girl (probably a natural "bleeder") in whom the hemorrhage from a bite continued for several days, until it became necessary to take her to New York City for medical treatment. In another instance one of several girls who were swimming beyond their depth became so panic-stricken on discovering a leech attached to her body that she lost self-control, sank and was rescued only with some difficulty. In most cases the attacking leech is pulled off, disposed of, and the incident quickly forgotten. Any detrimental effect was in general psychological rather than physical. It was noticeable that complaint was much more general and vigorous among directors of girls' than of boys' camps. Although leeches were little more familiar to the boys than to the girls, the former as a rule quickly learned their harmlessness and gave them little heed, regarding their attacks as merely of passing interest. Moreover, in many cases the widespread belief that leeches suck out the bad blood only, and are therefore beneficial, led many of the boys to consider a bite an asset rather than a liability. With the girls however, it was different. They regarded the leeches with disgust and horror, and many of them fled from them in real terror. It was found, however, particularly among the older girls, that a little instruction in the real nature of the animals, their essential harmlessness and their beauty and gracefulness, did much to calm these fears and to arouse interest. In some cases aquaria were placed in the camps and the study of leeches became a regular part of the natural history lessons.

The frequency of the bites was much less than had been anticipated from early reports. Very rarely is any one child attacked by more than a single leech, and it is seldom that as many as three or four out of a group of fifty or so swimming at one time will be bitten. For all the camps throughout the season the total number bitten daily would scarcely average ten. Altogether the actual problem seems not very urgent. Nevertheless it presents some aspects of interest and its potential importance renders its solution desirable. Some of these aspects may profitably be considered.

A usual effect of a leech's bite is a more or less intense and prolonged itching, which probably results from the injection into the wound of a natural haemolytic agent in the saliva. If the leech be permitted to complete its meal this substance is largely or entirely withdrawn from the wound, but if the meal be curtailed much of the haemolysin remains and acts as an irritant. Some persons are much more sensitive to the irritant qualities of leech bites than others, just as some are more sensitive to the poison of the bites of mosquitoes or other insects. To allay the itching a styptic pencil such as the barbers use, weak ammonia water, or witch-hazel extract may be applied with benefit. This is desirable, as scratching with dirty finger-nails may lead to infection of the wound, and apparently this entirely secondary effect is the chief source of injuries complained of, as in the case of many biting insects.

The hæmolysin prevents coagulation of the blood, which is the reason why a leech bite continues to bleed so much longer than an ordinary slight cut. The styptic pencil is the readiest means of stopping the hemorrhage. In the case of hæmophilics or "natural bleeders," like the girl mentioned above, whose blood does not readily coagulate, the addition of a further deterrent may cause the hemorrhage from even so minute a wound as a leech bite to become a possibly serious matter. Fortunately, such persons are rare.

The species of leech under consideration will draw at a meal about two to two and one-half times its weight of blood, while the European medicinal leech is reported to take from four to seven or even ten times its weight. As the usual weight of the leech in Carr Pond runs between three and five grams it is apparent that the amount of blood extracted from a vigorous child by one or even several leeches is negligible. Very rarely indeed does a child lose as much as one-half ounce of blood. It is obvious, however, that if many large and vigorous leeches should simultaneously attack a small, weakling child the resulting loss of blood might entail serious consequences. Many of the children attending these camps are ill-nourished, anaemic, and little able to afford any considerable loss of blood. Fortunately, from this point of view the leeches are present in the Palisades

Fig. 1. Carr Pond, as seen from a point on Seven Lakes Drive directly above Brooklyn Industrial Camp and Station 3, looking north-northwest.

Fig. 2. Carr Pond. Lower extension of lake partly filled, looking northerly from the old dam. (Figures 1 and 2 together cover the greater part of the lake except the section between the old dam and Jacob Riis Camp).

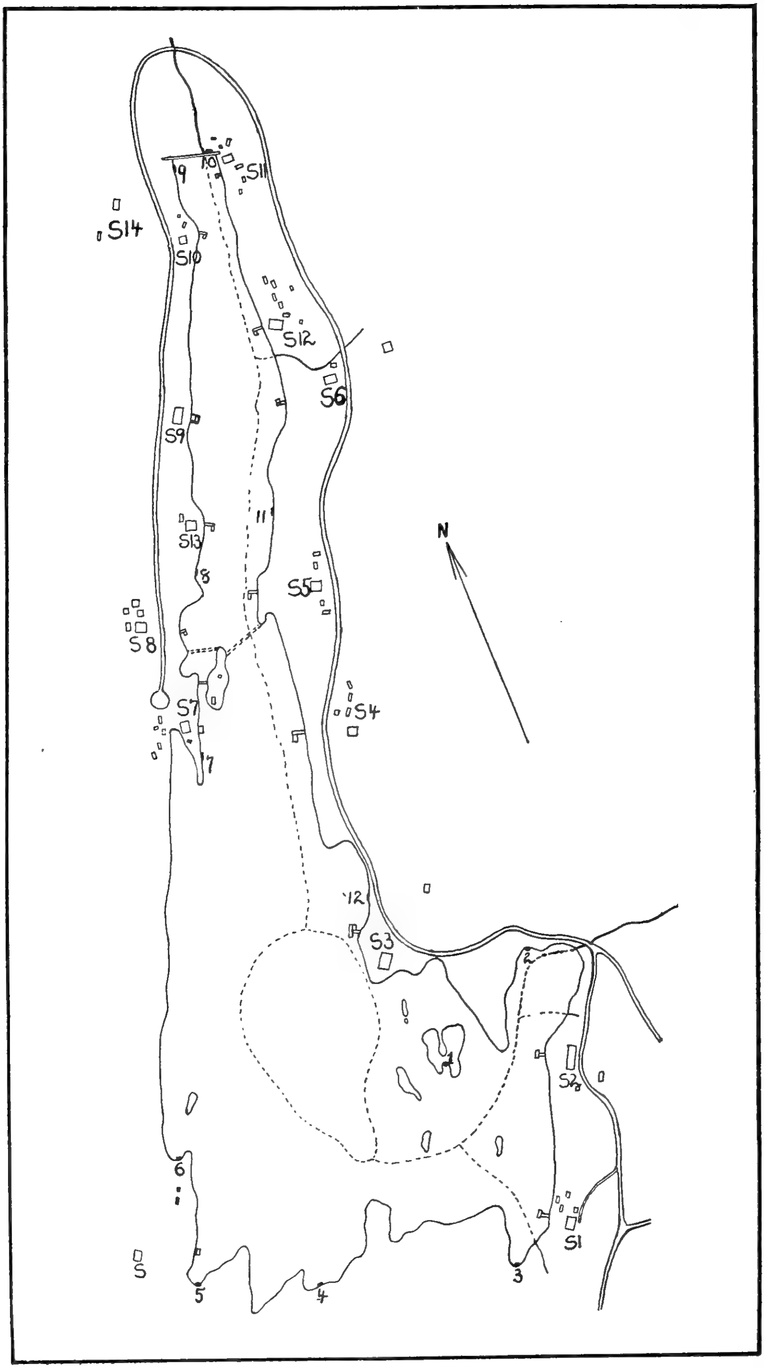

Fig. 3. Outline map of Carr Pond showing the road, camp sites, leech census stations, and in broken line, the old dam, the approximate location of the original pond, and the portion of Stahahe Brook submerged by the completed lake. Numbers 1-12, the leech census stations; S1—S14, the permanent camp sites; those mentioned specially in the text are Brooklyn Industrial (S1), Globe (S2), Jacob Riis (S3), and Kennedy House (S7).

Interstate Park in numbers insufficient to prove such a menace to any child sufficiently vigorous to enter the water. Cases have been reported from other localities, however, in which most serious consequences have resulted from the attacks of leeches upon children. A recent effort to secure authentic information relating to such reports concerning *Macrobdella decora* has failed. The older medical literature relating to blood-letting is filled with cases of accidents to young children through the careless application of leeches.

Blood-sucking leeches may be instrumental in the transmission of disease also. This may occur in two ways. A leech that has bitten and been removed may shortly after bite another individual. In this way bacterial or protozoan diseases may be carried mechanically. This sometimes happened in the practice of leeching when the same leech was used successively upon two patients without due precautions being taken. The danger is increased because of the habit of leeches of attaching to open sores, ulcers or boils. They will also attach to dead and decaying animals and thus may carry septic bacteria. The second possibility is that blood-sucking leeches may be the intermediate hosts of human parasitic diseases. No such cases are known at present but it is known that they bear this relation to certain parasites of the lower animals.

THE SPECIES OF LEECHES IN CARR POND

In all only nine species of leeches were found in Carr Pond and several additional ones in other waters of Palisades Interstate Park. Of these *Helobdella stagnalis* and *Glossiphonia picta,* the snail leeches, together with *Placobdella phalera, P. rugosa* and *P. parasitica,* the turtle leeches, belong to the family Glossiphonidae; *Erpobdella punctata,* the worm leech, to the Erpobdellidæ; and *Hæmopis grandis, H. marmoratis* and *Macrobdella decora,* the jawed leeches, to the Hirudinidae.

It will be noted that there are three species of large, jawed leeches. These are not discriminated by the campers, all being held equally guilty of blood-sucking. Much the largest of the three is *Hæmopis grandis* (Verrill). When extended in swimming this species ordinarily has a length of nine or ten inches and may be much larger, but it is seldom seen abroad during the day. It is possible that upon occasion it may attach itself to a bleeding wound but I have never known it to do so, and, as its jaws are entirely toothless, it cannot cut the skin as do the true blood-sucking leeches. Normally it burrows in the wet soil at the water's edge and feeds upon earthworms, smaller leeches and insect larvae. It will eat the young of the true blood-sucker and probably is a factor of some importance in checking that species. In Carr Pond it is very plentiful on the shores of shallows, especially at one open area along the southwestern shore where there is good garden soil.

Hæmopis marmoratis is a related species but is much smaller and darker colored. It seldom exceeds four or five inches in length and bears a few coarse irregular teeth in two rows on each jaw. While its usual food consists of insect larvae and small worms it will attack men and especially cattle wading in its haunts. In Carr Pond it is quite rare and of no significance in the present connection.

Finally there is the American medicinal leech, which must not be confused with the European medicinal leech (*Hirudo officinalis* Linnaeus) which has been introduced and become established in some parts of New York State. The following remarks on the European Medicinal Leech and *Hirudo colchica* by Dr. H. Grimm ('83, p. 54) are of interest. " The medicinal leech is spread all over Russia, being met with in the governments of St. Petersburg, Novgorod and Olonetz, and all the governments to the south of these. The number of places infested by leeches of course increases towards the south; but the real land of leeches is Trans-Caucasia, viz., the districts of the Black Sea, Poti and Lenkoran. The deeply-shaded rivers and forest-bogs of the Lenkoran district regularly teem with leeches so that it is impossible to bathe there. In every net full of ooze one draws up, some 20 or 30 leeches are sure to be found. In the forties, fifties and sixties of this century, when the use of leeches in medicine had reached its height, when the leeches in the Parisian hospitals alone sucked out 90,000 kilogrammes of human blood, and when 7,000,000 leeches were not enough for the London hospitals,— the demand for leeches, and therefore the sale of them, was very considerable in Russia. As the central and northern governments had not leeches enough of their own, the latter were brought (to Moscow as a centre) from Bessarabia, Astrakhan and Trans-Caucasia. It is true, a certain quantity of leeches was imported from Hungary, but then the Lenkoran leeches were exported.

" How great the sale of leeches was, can be judged (not having any statistics) by the fact that many Trans-Caucasians (chiefly the sectarian exiles) enriched themselves by exporting leeches.

" However great our natural supply of leeches might have been, it was apparently too small to satisfy the demand for them. So, on one hand, special orders were issued by Government (§ 562 v. XII C. of L.) 'rules for catching leeches in ponds and lakes,' (issued Sept. 21, 1848), which, by the bye, 1) forbade leeches to be caught during May, June and July, and 2) to take leeches either of too small a size (not less than 2⅝ inch.) or, large, old leeches, which were not fit for medicinal purposes, but only for propagation of the species, and 3) recommended the breeding of leeches.

"And on the other hand, leech-breeding establishments were started (apart from the above recommendation). Artificial leech-ponds (or parks) were built on Sauvet's system, for instance, in Moscow (M-r Parman), in St. Petersburg (M-r Gavriloff), in Piatigorsk, in Nijni-Novgorod, on the Ural (by Malysheff, the pisciculturist of 1855).

" Soon, however, all these measures became unnecessary. Doctors repudiated leeches. Yesterday, leeches were benefactors, today — they were dangerous and harmful, and were therefore left in peace in their native bogs."

The American medical leech, *M. decora,* though smaller than *H. grandis,* seldom exceeding six to eight inches in full extension and much less bulky, is nevertheless far more powerful and active. In spite of the belief of some of the camp directors to the contrary, all of my investigations showed that this is the only species that need be considered in connection with the attacks on bathers, though both *H. marmoratis* and *E. punctata* will attach themselves to bleeding cuts.

The following description shows that *M. decora* is a very clearly characterized species distinguished at a glance from any other American leech except the nearly related *M. sestertia* Whitman, which is a little known species not reported from this State.

THE NATURAL HISTORY OF MACROBDELLA DECORA (SAY) VERRILL

Description. The American medicinal leech may reach a length of ten or even twelve inches and a width of three-quarters to one inch, but such huge examples are rarely found, the usual length in extension being from three to six inches and the width about half an inch. The body is flattened throughout and the margins are sharp, much more so than in the species of *Hæmopis,* which in life are rather rounded. During life, however, the body is very soft and plastic and assumes an astonishing variety of shapes and interesting attitudes.

The anterior or oral sucker is a powerful organ provided with a rather wide, unsegmented, and very mobile border, which very materially increases its extent. Anteriorly, a distinct median notch corresponds with a deep ventral furrow which divides the upper lip and is flanked by a pair of slightly shallower furrows (figure 12, A). The upper lip can be folded into the mouth cavity and almost concealed by the lateral lobes that close beneath it. As usual in the family there are five pairs of eyes, which are larger than those of the species of *Hæmopis,* but similarly arranged in a regular submarginal arch.

When fully developed the clitellum or girdle is firm and thick and extends over eighteen annuli, from the last ring of the tenth segment to the second ring of the fourteenth segment inclusive, but it is seldom so well-marked or so extensive. In the ordinary condition the male genital pore appears as an opening of considerable size in the furrow between the eleventh and twelfth segments into which the surrounding rugosities converge. The inflected parts may be everted, as they are during sexual activity, when they form a prominent conical organ with deeply fluted sides and the small male aperture at the apex. The female orifice is a small opening with furrowed margins situated five rings behind the male pore. Very characteristic are the copulatory glands, which may be seen already in the leeches immediately after emerging from the egg capsules or when only three-quarters of an inch long. When fully developed they form a conspicuous group behind the female opening, occupying a large part of the middle area of the thirteenth and fourteenth segments. They open exteriorly on the ventral surface by four pores arranged at the angles of a nearly perfect square, two of them in the furrow between segments thirteen and fourteen and two in the furrow between the first and second rings of the latter segment. Surrounding each of the pores is a slightly swollen region extending over the contiguous halves of the two rings between which the pore lies. When fully developed in sexually active leeches the four swellings together form a conspicuous rough quadrate area extending over three rings and divided into quarters by narrow longitudinal and transverse diametral furrows.

The surface of the body is quite smooth and free from papillae although in some preserved specimens it may be somewhat roughened by the projection of the scattered sense-organs. This refers especially to the organs of touch or mechanical sense which are distributed over the surface of the skin generally but are especially numerous on the lips. Other sense-organs are those of taste, or chemical sense, located on the lips; the eyes, already referred to, which are strongly sensitive to changes in the intensity of light; and the sensillae, of which a circle occurs regularly on the middle ring of each segment and which are weakly sensitive to the same stimuli. The latter appear as minute clear white spots of which those on the dorsal surface stand out very conspicuously on the dark green background.

The external openings of the nephridia or kidney tubes appear as a pair on the under surface of the second ring of each of the fully developed or five-ringed segments of the middle region of the body. These are not, as formerly supposed, organs of respiration. It has been observed when the leech is drawing blood in the open air, as in blood-letting, that drops of clear fluid appear at these openings and flow over the surface of the body. This is believed to be derived from the blood-serum which is drawn off, thus greatly increasing the animal's capacity for the solid parts of the blood and at the same time serving to keep the skin moist. The anus is a small dorsal opening in segment twenty-seven immediately above the posterior or caudal sucker, which is a large and circular disk attached by a broad pedicle.

The mouth is of large size and may be considered as coextensive with the entire opening of the oral sucker, the upper lip of which overhangs it. The jaws have the usual triradiate arrangement, but among the leeches of the United States, the form is characteristic. They are compressed and about twice as long as high, and each bears along its ridge a single row of about sixty-five fine, conical, slightly retrorse teeth with bilobed bases. A very short muscular pharynx, with the lining thrown into several longitudinal folds, reaches to about the ninth segment, within which is a still shorter œsophagus scarcely to be distinguished from the croplike stomach, inasmuch as the sacculations begin immediately. From the tenth to the eighteenth inclusive each segment includes two pairs of lateral gastric cæca, of which those from the thirteenth backward are of large size and branched. The last pair, which originate from the stomach in the

Fig. 4. General conditions near Station 1. View south from Jacob Riis Camp. Station 1 is on the far side of the rocky point, almost in the exact center of the photograph, below the gap through which the main Park road approaches the lake.

Fig. 5. Head of Globe Camp Bay, showing conditions at Station 2, looking southwest. The exact position is at the extreme right of the water shown.

Fig. 6. Conditions at Station 3, head of Brooklyn Industrial Camp Cove, looking north by east.

Fig. 7. View of south shore, looking westward. Station 4 is just beyond the rocky point where a grassy slope reaches to the water's edge. Small pieces of floating islands shown.

latter part of the nineteenth segment, are of very great extent, reaching backward into segment twenty-four or twenty-five and bearing two wide lateral branches in each of the intervening segments. The straight narrow intestine presents no noteworthy features.

While presenting the general features characteristic of the family the reproductive organs (figure 12 B, and 12 C) are in many details peculiar. There are ten pairs of testes situated at the boundaries between contiguous segments from the thirteenth and fourteenth to the twenty-second and twenty-third inclusive. Their delicate ducts, all of which unite in a pair of longitudinal canals, the vasa deferentia, are like the latter covered with minute unicellular glands and follow a somewhat winding course. The glandular coat ceases at the eleventh segment where the vasa appear as smooth very delicate tubes, and at the level of the ganglion of that segment pass abruptly into the pair of massive compact epididymes. From its posterior end each of the latter is continued as a rather wide somewhat folded ejectory duct leading to the single median terminal or copulatory organ. Just before entering the outer or glandular layer of the so-called penial bursa, or atrium, the ducts become constricted and then rise as a pair of slightly enlarged sacs which open into the summits of the large inner end of the bursa, to which they stand in the relation of a pair of horns. This median bursa which evaginates to form the penis is in its retracted condition spherical or inverted pyriform in shape, and its thick walls consist of mucous, muscular and glandular coats. Within it the spermatophores or bundles of spermatozoa which are transferred during copulation, are formed.

During life the colors are very rich and showy. On the upper surface the ground varies from a light sage-green to a dark olive-green with obscure dark longitudinal lines or streaks in the median area. Down the median line is a series (sometimes absent) of small but very conspicuous cadmium-orange or light red spots, one to each segment. On each side close to the margins is a similarly arranged series of small black spots. The lower surface is of rich orange varying in shade and intensity, sometimes plain, sometimes spotted to a varying degree with black.

Distribution, Habits and Ecological Relations. The American medicinal leech is widely distributed throughout the northern United States and southern Canada. It extends across the entire width of the continent and has been taken in every state from Maine to Washington. The known north and south range is from Labrador to Kansas and Virginia. In the southern United States it is replaced by other blood-sucking leeches of the genera *Macrobdella, Philobdella* and *Limnatis*.

In the Palisades Interstate Park this leech is more plentiful in Carr Pond than elsewhere, though it occurs in smaller numbers in some of the other lakes but not sufficiently to be considered a pest by bathers. Even in Carr Pond it is not nearly so abundant as in many ponds in eastern Pennsylvania and Massachusetts, or in the lakes of Wisconsin and Minnesota. Observations made at the swimming places (figure 9) when the splashing of twenty to fifty boys or girls in the water stimulated the leeches to great activity, seldom revealed more than two or three swimming at a time. Receptacles placed at the camps with instructions that all leeches caught be placed therein rarely yielded more than three or four as a day's catch at any one camp. By collecting generally along the shores usually fifteen or twenty could be gathered in a morning. I have taken several times that many in the same time in eastern Pennsylvania and elsewhere. By direct observation, especially at marked stations of equal areas, and by the use of the receptacles above mentioned, it was found that the distribution in Carr Pond during the summer of 1919 was not uniform. Few leeches were found in the newer part of the lake near the dam. They were several times as numerous in the body of the lake, and were especially plentiful about the shallows in the vicinity of Globe (figure 5) and Kennedy Camps and in the small cove near Mr. Herbert's shack (figure 8). It seemed evident that the lake had been stocked from a nucleus in the original pond and that the leeches had not yet attained their maximum numbers or moved freely into the new part of the lake.

Ecologically considered *Macrobdella* is a swamp rather than a pond animal. Normally it is an inhabitant of the shallows and the vicinity of the shoreline where land and water meet. It may be found concealed under stones and logs, more especially those that lie partly out of the water. Here when well fed it rests quietly, or when hungry lies in wait for frogs, warm-blooded animals that enter the water, or other prey (figure 13, A, B). Any disturbance of the water such as is caused by a wading animal attracts them, partly because of the mechanical disturbance which stimulates the tactile organs and partly because of the animal emanations that stimulate the organs of chemical sense. Advantage of this peculiarity is taken in collecting them. On stirring up the bottom with one's bare feet any leeches that happen to be in the neighborhood may soon be observed swimming or creeping toward the place, and may be allowed to attach themselves to the skin and be picked off. Anglers quite often find one or more of them attached to catches of fish which have been strung and placed in the water where their lashing and bleeding serve as attractions.

Observations through the summer make it quite evident that the leeches are attracted by the bathers also. They congregate and remain about the docks and beaches, concealing themselves in the crevices of the woodwork or among the stones, and issuing at the bathing hour. Complaints of attacks became somewhat more frequent during the latter half of the summer and there appeared to be a corresponding decrease in their numbers at points elsewhere. Having fed at the bathing places they become quiescent and remain. Consequently they become concentrated at these places and there is a relative decrease in numbers elsewhere, as suggested. This is probably due in part to the fact that they become more active with increasing temperature and consequently move more freely as the water warms. The period of greatest prevalence at the docks corresponds with that of maximum temperature of the water in August. While the excursions of the leeches into the open waters are concerned primarily with the quest for food they serve also to extend and alter their distribution. They are strong and rapid swimmers, progressing with easy and graceful dorso-ventral serpentine movements during which the body may be turned either vertically on edge or flatwise.

Every feature of their organization shows that these animals are beautifully adapted to a habit of occasional and temporary parasitism and a sanquinary diet. The acute chemical and mechanical senses, the powerful organs for rapid and varied locomotion, the soft and sinuous body, the concealing coloration, the strongly developed organs of attachment, the finely fashioned instruments for painlessly cutting the skin and capillaries, the haemolysin and powerful pumping apparatus for facilitating the rapid flow of blood, and the great storage capacity and ability to subsist without food to tide over periods of scarcity are among those that appeal especially to students of adaptation.

When biting the leech usually attaches itself firmly to its host by the caudal sucker, the anterior end of the body meanwhile exploring for a suitable place to bite, preference being given to a cut or abraded spot, or, in the absence of such, to a tender vascular area of the skin. To this the oral sucker is then applied intimately and fixed firmly, and the jaws are pushed forcibly against the surface. By a rotary back and forth motion toward and from the center of the radially arranged jaws effected by two sets of oblique muscles, the numerous fine teeth cut three narrow deep slits together having a characteristically trifid pattern. The salivary secretion, containing the haemolysin called hirudin, pours over the jaws directly into the wound and mixing with the blood keeps it fluid and facilitates its flow. By the action of the bulbous pharynx the blood is pumped from the wound into the gastric or crop cæca which may become filled in about fifteen or twenty minutes. If the stomach of a feeding leech be cut into from the exterior the blood will flow from the opening in pulsations. The quantity of blood taken by leeches of the size commonly found in Carr Pond is from six to fifteen grammes but may vary between much wider limits depending upon the size of the leech and the nature of the host.

After completing a meal the leech drops off and being then negatively phototropic (that is, tending to move away from the source of light) it seeks the darkness under stones or logs, in crevices, or in burrows in the mud. Ordinarily it does not feed again for several weeks or even months, but is less abstemious than the European medicinal leech, which is said habitually to allow five or six months to elapse between meals. A leech may live indefinitely without food. Two years and more has been recorded for the European leech and I have kept *Macrobdella decora* alive without food for from seven to fifteen months. Under such circumstances they shrink greatly in size. For example, in the experiment covering fifteen months the average weight of five leeches fell from 3.09 grammes to 0.79

grammes. In correspondence with the extreme slowness and completeness of digestion the intestine is short and simple and the anus is minute.

As indicated, the food is typically vertebrate blood derived from men or cattle entering the water, or in their absence from frogs (figure 13, B), tadpoles, fishes or turtles. Frogs' eggs, (figure 13, C) aquatic worms (Tubificidae), and occasionally insect larvae are also eaten. In attacking fishes, favorite points are the gills and isthmus, both highly vascular regions. In the case of frogs the leech will sometimes perforate the skin and insert the cephalic end into the subcutaneous lymph spaces, in which case the large blood vessels may be reached and death result very quickly.

These leeches are extremely sensitive to the presence of food. If, in a vessel containing several, a finger be touched lightly on the bottom, after a short interval the leeches become restless and begin exploratory movements in the course of which the head is passed over the spot touched and immediately arrested, upon which increased excitation follows with more minute and long continued exploration of this spot. It is quite evident from their actions that they detect the presence of the emanations left by the finger. A little blood escaping from a cut is an even greater and farther reaching attraction, and the leeches will gather from considerable distances to the promised feast. This habit may be taken advantage of in collecting the leeches and has been used effectively by the writer in the vicinity of Philadelphia. Movements of the water and the disturbance of the bottom such as results from men or cattle wading or swimming also attract the leeches even when animal odors are eliminated, as is shown by wading in rubber boots or by the use of a pole. After such disturbances the leeches may be seen leaving their places of concealment and crawling or swimming in search of the expected prey, if one may so express the reaction in terms of the consciousness that the animals lack.

Ordinarily *Macrobdella* is negatively phototropic, remaining concealed in dark places during the day and becoming active at night when presumably frogs and fishes are naturally preyed upon; but if hungry the impulse aroused by the stimuli indicating the presence of food overcomes the impulse toward concealment and they will swim freely during daylight. Otherwise this study would not have had its inception. When well fed they remain quiescent and relaxed under stones and logs near the water's edge, assuming a variety of resting attitudes often partly out of the water. This latter habit is well illustrated when they are kept in the laboratory in aquaria, in which case a favorite position is with one or both suckers attached to the glass above the water's edge, the body being permitted to hang laxly more or less into the water.

Under such circumstances the supply of oxygen is abundant and no respiratory movements take place, but when immersed in water in which the oxygen supply is deficient they exhibit rhythmic undulatory movements that may be quickened or retarded by other stimuli, such as arise from light changes or contacts. This movement varies

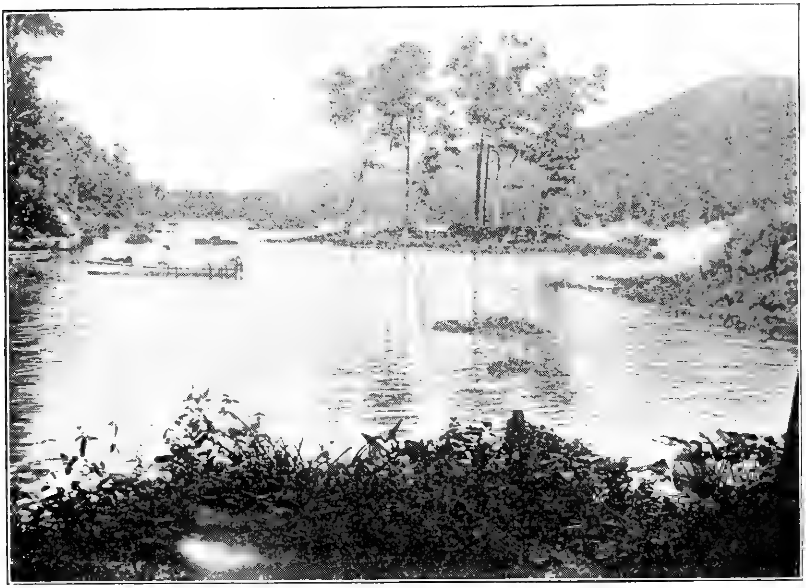

Fig. 8. Cove just north of Herbert's, looking down the lake. Station 6 is in the immediate foreground, and conditions here are similar to those at Stations 5 and 7.

Fig. 9. Swimming beach on new extension. Station 11 is just outside of the picture on the right, where shore conditions are similar. The new dam, shown about a third of a mile below, is the location of Stations 9 and 10.

Fig. 10. Cove at Jacob Riis Camp, showing shore conditions at Station 12.

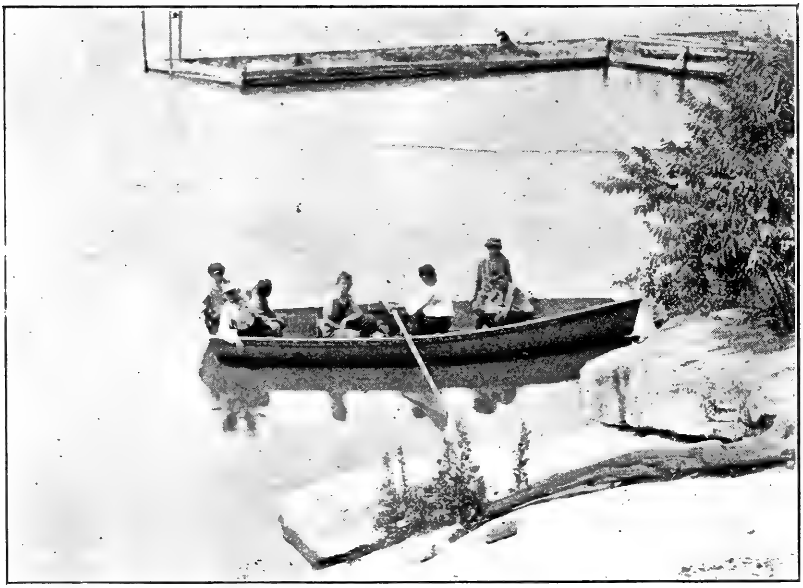

Fig. 11. A swimming dock and boat landing at Carr Pond.

in rate, amplitude, and vigor as determined by a great variety of conditions. It may occur during feeding, when probably it has the additional utility of facilitating the filling of the cæca. Leeches are able, however, to live under nearly or quite anærobic conditions (Putter, '07).

As in most aquatic invertebrates the rate of metabolism, and consequently of the activities of leeches, is a function of the temperature, increasing as the water becomes warmer to an optimum not yet accurately determined, and diminishing as it cools. This is probably another reason why these leeches seek the shallows where the water is warmer during the greater part of the year and especially during the spring. In the autumn as the water cools the leeches remain much of the time quiescent and probably seldom feed. When the water temperature approaches 40°F. they become extremely sluggish and seek winter quarters, and at 39°, the temperature of greatest density of fresh water, they become practically dormant and nearly insensitive but will respond by slow movements if pinched with a forceps, pricked with a needle, or exposed suddenly to a strong light. At this time they appear to be somewhat reduced in size and it may be that, like earthworms and many other animals at low temperatures, they have lost water, but this has not been determined.

In the vicinity of Philadelphia *Macrobdella* may be found throughout the winter on the tidal flats of the Delaware River or on the shores of ponds beneath logs and stones partly buried in the mud and seldom in water more than eighteen inches or two feet deep. In such places they may or may not have burrowed two or three inches into the mud and appear quite dormant until, with even a slight rise in temperature, they are stimulated to show some activity. Leeches of this and other species are frequently found in nature in a lethargic state in the unfrozen mud immediately beneath the ice or in actual contact with or even imbedded in the latter.

That they are quite unharmed by freezing temperatures, I have many times demonstrated in laboratory experiments in which the water in the vessel containing them was wholly or partly frozen; and they have lived thus for several days, showing no indication of injury whatever when gradually thawed out. Further experiments, conducted both during the summer upon active leeches and during the winter upon individuals naturally dormant, have fixed with sufficient accuracy for present purposes the lethal point to cold. It has been found that a temperature of 20° to 22°F. was invariably fatal even when the exposure lasted for only three to eleven hours and the thawing out was very gradual. These experiments were conducted by placing two or three healthy leeches at a time in basins or tight boxes about five inches deep, either with water only or with three or four inches of wet mud, sand, stones, and bits of bark in and beneath which the leeches were buried to varying depths. The vessels were then placed either on ammonia coils in a freezing room, in ice and salt mixtures, or during the winter out of doors. The air temperature and the temperature of the contents of the vessel were determined, the former usually by an ordinary house thermometer and the latter by a Centigrade chemical thermometer encased in a brass tube. All of the experiments on both dormant and active leeches fixed the lethal temperature at about 20°F. When thawed out slowly and carefully after such freezing the leeches were always found to be completely dead, very much relaxed, somewhat swollen, soft and flaccid, very different from the more or less rigid, turgid state of these leeches when killed by strong mineral or narcotic poisons.

In the spring as the water warms the leeches gradually become active, appearing with the frogs upon which and their eggs they largely feed (figure 13, B, C). At this time, and to a less extent later in the summer, and then only when unfed, they are prone to wander. If kept in an aquarium they will frequently crawl over the sides during the night and occasionally even by day and drop to the floor. I have often found them by following the glistening trail of dried mucous wiped free of all dust and meandering about the floor for perhaps as much as one hundred feet. When found the leech will present a shrunken, more or less dried appearance, and will be covered with adhering dust. If too great a time has not elapsed they may be revived by immersion in water even after shrinking to one-third of their former size and weight. The principal loss has been of water in the form of mucus, and absorption of water takes place rapidly, the animals soon regaining their normal size and activities. This peculiarity is of much value to individuals of the species living in small rain-fed ponds from which the water completely evaporates during dry summers. Under such circumstances these leeches bury themselves in mucus-lined mud cells beneath stones and logs, shrink in size and become dormant. How long they will live under such conditions has not been determined, but they have been found unharmed after such a pond has been dry and the bottom mud hard and cracked for three or four weeks.

When the leeches become active in the spring they are usually voracious and feed eagerly. After being well fed they copulate. In this act the ventral surfaces of two individuals are brought together in the region of the genital pores, the heads being pointed in opposite directions (figure 13, D). The glairy secretion of the copulatory glands aids cohesion, which is further assisted by one or both individuals taking a loop round the other or by attachment of the suckers. The muscles in the genital region contract strongly, often forming a constriction, the penial or copulatory bursa is everted, and the contained spermatophore attached within the vagina of the other individual or at its orifice. The transfer of a spermatophore may be reciprocal or one-way.

The actual formation of the egg-capsules (figure 14) has not been seen in this species, but during June and July they have been found buried in the mud or turf at the water's edge just above or below the water level. They vary from less than one-half to about three-quarters of an inch in length, probably dependent on the size of the producing leech. In shape they are broadly elliptical and in color a pale straw. The structure resembles that of other leeches of the same family, the walls being composed of a cellular spongy layer of chitinoid material nearly one-eighth of an inch thick, and perforated almost completely at each end by a tubular canal. Lining the spongy layer is a thin membrane of the same material but without spaces or openings. The cavity within is filled with an albuminous mucus similar in appearance and properties to that found within the capsules of earthworms. Imbedded in this are several eggs or young. The exact length of time required for hatching is not known for *Macrobdella,* but is about three weeks and varies with the temperature. Newly emerged young (figure 14) measuring from five-eighths to three-quarters of an inch long in extension are frequently found during July and August. They are easily recognized as they possess the characteristic color markings and the copulatory glands are distinguishable on examples three-quarters of an inch long. According to Rathbun ('84) this species matures in two or three years in the leech farms.

While a great deal has been written about the enemies of the medicinal leeches under cultural conditions fifty years ago, when the matter was of considerable economic importance, little of a specific nature is recorded concerning the enemies of our leeches in the wild state. Doubtless predacious fishes are the principal enemies of the developed animals, though the worm leeches (*Erpobdella*) appear to fall a prey more often than do the jawed leeches. I myself have found them in the stomachs of black bass and sunfish only, and even in these but very rarely. Zoological literature records them among the food of a variety of species. A foreman in the Park, Mr. Herbert, reports that in the late fall of 1917 he examined the stomachs of several yellow perch taken in Carr Pond, and found them to be filled with large dark colored leeches that he thought were *Macrobdella decora.* During July and August, especially the latter, Mr. Fletcher and I caught numbers of yellow perch (together with common and long-eared sunfish and catfish) in Carr Pond in the hope of confirming this statement, but in no case were any leeches found in the stomachs. As this perch is abundant and of large size in Carr Pond any general use by it of *Macrobdella* as food should exert an important repressive influence. That fishes will eat leeches is evidenced by their value as bait. For this purpose their toughness, rendering them difficult to strip from the hook, makes them superior to earthworms and they seem equally attractive, as I have found personally in the cases of sunfish and perch. In many parts of Pennsylvania country boys habitually employ *Erpobdella* and *Hæmopis* for this purpose, and *Macrobdella* is said to be so used in the lakes of Minnesota and Wisconsin. Professor T. L. Hankinson tells me that he has employed them successfully, and at the writer's suggestion some of the campers on Carr Pond took up their use to a limited extent.

Aquatic birds probably destroy many leeches. I have found them in the stomachs of both wild and domestic ducks. It seems probable that small species, together with the eggs and young even of *Macrobdella,* may often fall a prey to the sandpipers and plovers that habitually feed among the shingle and shore debris where small leeches especially abound.

Rats, minks, small herons, kingfishers, crows, turtles, snakes, crayfishes and various kinds of predacious insects and their larvae may exert some influence, as they were known to do on the leech farms. Among other leeches, the large *Hæmopis grandis,* which is plentiful in association with *Macrobdella decora* in Carr Pond, is undoubtedly an important enemy of the latter. This leech habitually feeds upon earthworms, smaller leeches and insect larvae, and has been observed to devour *Macrobdella decora* two inches long. As it lives in the very places where *Macrobdella* deposits its egg-capsules it is probable that it destroys large numbers of the newly hatched young of *Macrobdella.*

METHODS OF CONTROL

In the effort to devise a practical solution of the problem every known aspect of the life history, habits and reactions of this species, of which a general outline has just been given, was passed in review in the hope of finding a weak spot at which it could be successfully attacked. Many methods were considered and experiments tried, the most important of which will be described.

Baiting and Trapping. In my previous experience in collecting blood-sucking leeches frequent use had been made of baits of freshly killed and bleeding small animals and of slaughter-house blood placed in a muslin bag dragged through the water or simply placed in the water and allowed to diffuse. This latter was a method of feeding leeches largely employed in the days of hirudiculture. Both of these methods had been found effective in attracting them, and large numbers of *Macrobdella* and other leeches were often gathered in a short time by simply catching them in a dip-net as they swam toward the baits, or by picking them by hand after a number had attached themselves to the bag or dead animal. It was thought if such baits were placed in a trap easy of entrance but difficult of exit for the leeches that considerable numbers could be gathered automatically and disposed of. Indeed, before visiting the Park this method had appealed to me as likely to meet with success. As soon, however, as I saw the size of Carr Pond and the actual conditions existing there I lost faith in its practicability. Nevertheless a series of experiments with baits and traps, partly in the laboratory, partly in the field, were decided upon.

Three forms of traps were devised and tried. The first (figure 15) was constructed on the well-known principle of the lobster pot. It is a box 24 x 18 x 18 inches built of light, matched partition boards with the top hinged to afford access to the interior. The front has the form of a deep reentering angle (figure 16) running the entire length of the box. The pieces composing this angle fail to meet at the apex, leaving a slit one-fourth inch wide which is continued by two parallel boards as a passage of the same width four inches further into the interior, thus giving the effect of a horizontally extended

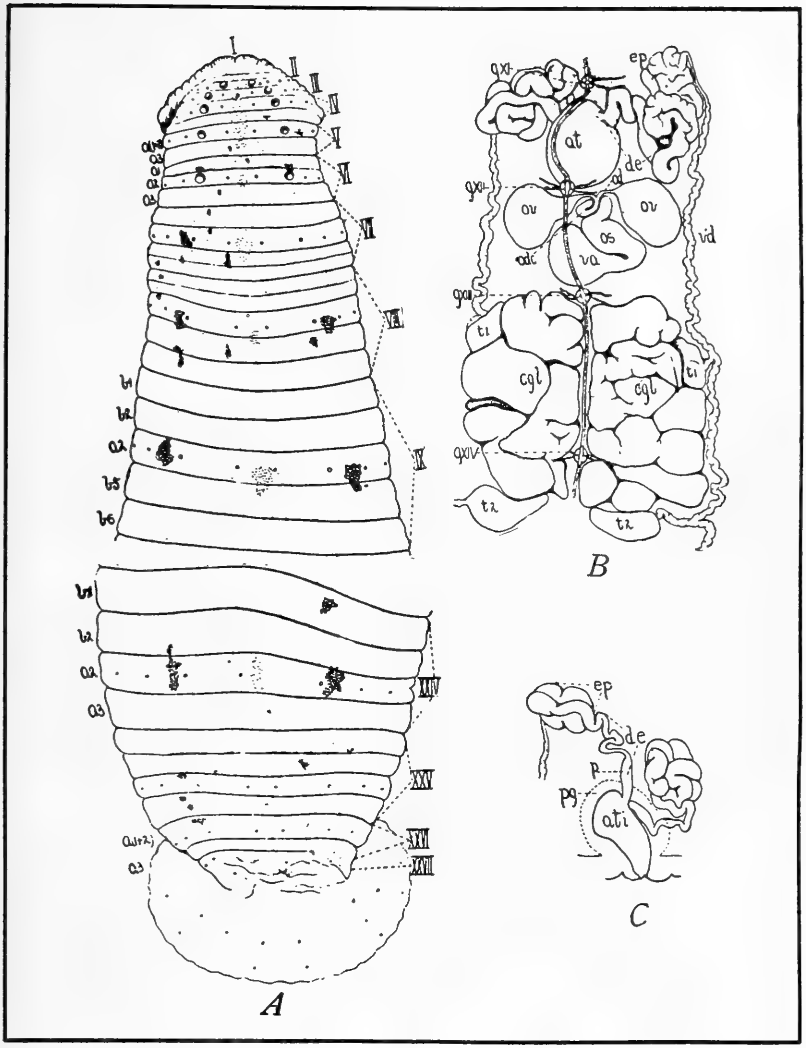

Fig. 12. Characteristics of *Macrobdella decora*. A: Details of exterior of anterior and posterior ends showing arrangement of somites (I to XXVII,—X to XXIII inclusive are omitted), annuli (a^1–a^3, b^1–b^6, etc.), eyes, segmental sense organs, color markings, suckers, anus, etc. (From Leeches of Minnesota, Nachtrieb et al, '12). B: Dissection of reproductive organs seen from above. *at,* atrium or penis sheath; *cgl,* copulatory glands; *de,* ductus ejaculatorius; *ep,* epididymis; *gXI* to *gXIV,* ganglia of the ventral chain; *os,* ovisac; *ov,* ovary or ovarian sac; *od,* oviduct; *t1, t2,* first and second pairs of testes or testicular sacs; *va,* vagina; *vd,* vas deferens. C: Male organs dissected and viewed from the right side. The left sperm-duct retains its natural position; the right is displaced upward, and the dotted line shows the outline of the atrium before the removal of the layer of muscles and prostate glands. *ati,* internal layer of atrium; *de,* ductus ejaculatorius; *ep,* epididymis; *pg,* prostate glands and muscles; *p,* prostate cornua of atrium. (B. and C. from Hirudinea of Illinois, Moore, '01).

Fig. 13. Activities of *Macrobdella decora.* A: resting and swimming positions (note that the swimming leech is turned on edge). B: attacking and feeding upon a frog which has nearly succumbed to the loss of blood. C: feeding upon frogs' eggs; two leeches have penetrated the mass and are rapidly cutting the eggs from their envelopes and swallowing them; of the remaining two, one is swimming, the other exploring while the caudal sucker remains attached. D: a pair of leeches in copulation; this figure represents *Philobdella*, a southern leech related to *Macrobdella*. A, B and C are reduced. D is nearly natural size.

funnel with the wide opening outward. In the upper sloping face a row of holes was bored and covered with wire mosquito screen. Except for these openings and the slit-like entrance the box was quite tight. In using the trap a bait of freshly killed frogs or more frequently a duck bag filled with fresh blood was suspended inside from the top in such a position that the blood dripped onto the upper sloping side and trickled through the openings above the entrance. The box was then weighted with stones and sunk to the bottom in shallow water close to shore.

The theory of operation of these traps is as follows. The blood flows from the openings above the entrance and diffuses into the surrounding water. Judging from the known habits of the blood-suckers, any in the vicinity might be expected to be stimulated by the scent or taste of the blood to follow the trail to its source where the convergent sides of the funnel would direct them to the entrance through which they would crawl into the interior. Once within the box they would quickly find and attach themselves to the bait and after satisfying their appetites would drop off and seek a dark shelter as is their habit. This would be afforded by the lower chamber of the trap where it was expected they would remain quiescent and satisfied until the trap was examined on the following day. Even should some of them become restless and crawl or swim about there would be little chance of their finding the narrow opening by which they entered, and the more direct openings for the diffusion of blood are in the upper chamber and guarded by a screen.

Three of these traps were made and set at favorable points chiefly in the shallows at the southern end of the lake where the leeches were most common. They were shifted about from time to time in order that as many conditions as possible might be tested. They were baited as often as fresh bait could be procured, that is, two or three times a week for five weeks, and were always examined on the following day. In some cases a bag of blood was dragged over the bottom near the shore in both directions from the trap to establish a better trail. Detailed records of each trap were kept but are not worthy of publication. Suffice it to say that in no case was more than a single leech found in any trap and more frequently there was none. Freshly killed frogs proved a more attractive bait than slaughter-house blood. Concerning the ineffectiveness of the latter see the remarks under the account of laboratory tests of baits.

The second form of trap (figure 15) is a rectangular bag of duck, the mouth of which is supported by a heavy wire frame. From the mouth two duck flaps six inches wide project obliquely into the interior and converge till they nearly meet, their free edges being held in position close together by being stretched on a heavy wire rod. The general effect of this trap is similar to the box trap, but the blood bait diffused into the water through the sides generally as well as through the narrow mouth. It was baited, weighted and sunk at suitable points, usually being suspended above the bottom from an anchored buoy by cords attached to the wire frame so that the opening was above. This trap proved a total failure. Not a single leech was caught by it.

The third form of trap was a little pen four feet across, constructed of four boards driven into the bottom and the banks and fastened by stakes, the whole having the outline shown in figure 17. This was constructed at a shallow point on the south shore where a saw mill had been operated, and where some old boards were lying about to afford shelter for leeches. The bank here is about a foot high, abrupt, and composed of a rich black earth covered with a good growth of grass. The depth of water within the pen varied from ten inches at the outer to four inches at the shore end. Several flat stones and pieces of board were placed within to afford concealment for any leeches that might enter. The trap was baited with blood as were the others, and although used for only one week in the latter part of August proved rather more successful than the other traps. Three visits yielded seven leeches, though it is not certain that some of these may not have been overlooked when the bottom and banks were thoroughly searched for leeches before the trap was baited.

From these experiments the impracticability of trapping, at least by any of the methods adopted, was thought to be sufficiently established. Certainly these traps proved far less effective than human traps in the shape of boys at the swimming docks.

Even had the traps proven several times as effective the expense would have condemned their use. Various experiments and observations would indicate that under ordinary conditions which, of course, vary greatly, the average range of attractiveness of a leech bait does not exceed an extreme limit of fifty feet in any direction. This would give to each trap a maximum effective range of about 100 feet of shore. The shore line of this lake is approximately four miles or 21,180 feet long. Consequently a complete line of traps around the entire lake would require not less than two hundred. The expense of tending the traps would also be heavy. Mr. Fletcher and I working together found that about twenty minutes were required to raise, examine, clean, rebait and set one of the experimental box traps. With an effort directed toward speed, and with improvements in the manner of weighting and for facilitating the escape of air so that they would sink more rapidly this time could be cut in two, making six traps per hour or forty-eight per day of eight hours for two men. The entire time of four to eight men would therefore be required for this work.

There being no local slaughter-house some difficulty was had in arranging for a regular supply of blood. This was finally secured from New York abattoirs through two avenues, Mr. Daschner of the Bear Mountain Inn and the Tuxedo Meat and Provision Company, to both of whom my thanks are due. The blood was shipped on ice in glass jars or tin cans and always reached me in good condition. From the first it was noticed that it remained fluid, was of a remarkably bright red color and would seldom putrefy until the third day, even during the warm weather of midsummer. For this reason it was suspected that it might have been treated with an artificial preservative, especially as it appeared to be so much less effective than blood previously used at Philadelphia. Inquiry brought the assurance that it was "pure heart blood" of the beef entirely without preservative or treatment of any kind. Some experiments conducted in aquaria in the laboratory showed that the leeches would follow a clear trail of this blood and that they would eat it, though with much less eagerness than the fresh blood of frogs.

Before a supply of fresh blood was arranged for, some laboratory experiments were conducted on several substances in the hope of finding a satisfactory substitute for use as bait. Among the substances tried were dried blood (commercial fertilizer), beef extract (Armour's), musk, urine, and oil of anise. By far the most active response was made to the beef extract, which was readily traced across the aquarium to the finely drawn out end of a tube from which it was slowly diffusing. It was also imbibed to a limited extent. In about half of the experiments with dried blood this also induced a positive reaction but in no case did the leeches appear to eat it. To the musk there was only a very weak response, and to the urine and anise oil there was no appreciable positive reaction.

Gathering the Leeches and their Egg-cases. Up to a half-century ago the use of blood-sucking leeches for medicinal purposes continued of sufficient generality that, in addition to importations from Europe and the product of American leech farms, large numbers of our native wild leeches (*Macrobdella*) were utilized. Especially in the environs of Philadelphia several collectors maintained a considerable and profitable business. The leeches were obtained chiefly from the ponds of Montgomery, Bucks and Berks Counties, and on the tidal flats and marshes on both sides of the Delaware River. After the decline of this business *Macrobdella decora* increased greatly in numbers in this region. During the progress of the World War, with other supplies cut off, there arose a slightly revived demand for native leeches, especially among the foreign population of New York and other large cities, and some inquiries were made by pharmacists and chemists for leeches as a source of supply of hirudin for use in surgery. During my visit to Carr Pond some interest was aroused among a few of the more commercially-minded boys at one of the camps, and they were influenced to gather some of the leeches and dispose of them at a fair price to a dealer in New York City. If it could be done without conflicting with the ideals and discipline of the camps this practice might be largely extended, and in the aggregate a considerable number of leeches got rid of. Probably much more could be accomplished in this way than if men were employed to gather them, and without any expense to the commissioners. No better opportunity for collecting them can be devised than that presented during the swimming periods at the camps, the swimmers themselves serving at the same time as animated baits and traps. Were this plan carried out consistently at all of the camps for a period of years it is certain that a very material reduction in the numbers of the leeches would be witnessed. General collecting along the shores would be facilitated by placing boards at the edge of the water for the leeches to gather under. As other incentives to gathering the leeches may be suggested the offering of prizes and instruction in their use as bait. Little could be expected from the crudely improvised tackle and haphazard methods of fishing of the smaller boys, but for the older boys and camp leaders with their better tackle and greater expertness, leeches can be recommended as a most effective and a satisfactory bait for bass, yellow perch, the larger sunfishes and similar fishes.

The eggs of *Macrobdella* are encased in spongy capsules (figure 14) deposited for the most part in the mud and turf at the water's edge. Occasionally considerable numbers of these are found in favorable spots. It was hoped that at Carr Pond the leeches might congregate at localized breeding grounds where the egg-cases would be found in large numbers. This hope was disappointed, however, and only a very few widely scattered capsules were found. Under these conditions collection and destruction of these would be futile. It is doubtful if any physical means for destroying the egg capsules in large numbers could be applied successfully, as they are very resistant to drying out and to mechanical and chemical injury.

Use of Natural Enemies. As stated above, very little of a specific nature is known concerning the natural enemies of native American leeches, and particularly of *Macrobdella decora.* It may be safely assumed, however, that the American counterparts of those animals which have been ascertained to prey upon the European medicinal leech will prove to be factors in the restriction of ours also. As many of these are represented in the fauna of Carr Pond, collectively they doubtless exert an important influence in keeping the blood-sucker and other species of leeches within numerical bounds. Probably the most important of such enemies in Carr Pond are certain species of carnivorous fishes (sunfishes, yellow perch, black bass, etc.), the spotted sandpiper, green heron, belted kingfisher and wild ducks, water snakes, frogs and newts, predacious insect larvae, especially *Dytiscus* and some of the larger dragonfles, and the large toothless leech. Nothing is known of the diseases of wild leeches, though in confinement the mortality of the medicinal leech through infection is very considerable. Doubtless little can be done to combat the leeches through the further use of natural enemies, inasmuch as it is probable that a balance between all of the interacting factors has been or soon will be reached and maintained. Some repressive effect might be had by encouraging the increase of certain desirable species of fishes such as those mentioned above, or by introducing crayfishes, of which I saw no examples in Carr Pond; or by destroying their shelters by clearing up the shorelines of boards, logs, etc., as was done among the measures taken against mosquito breeding. However, owing to the activity of the leeches and the ease with which they can adapt themselves to the abundant places of concealment the latter would probably avail little.

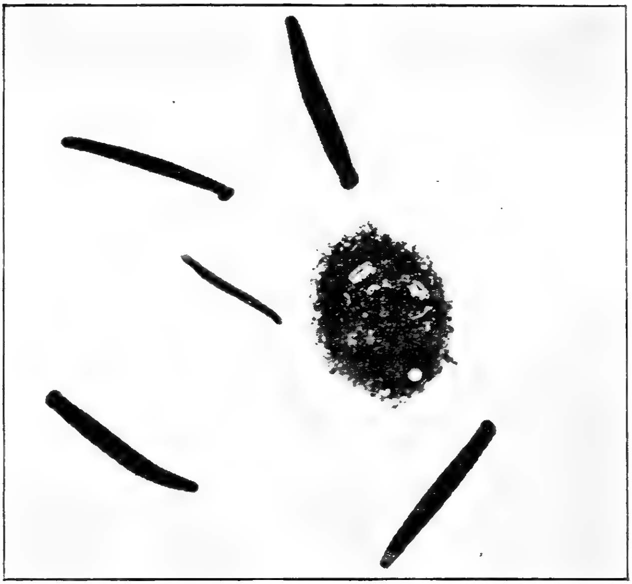

Fig. 14. Egg case and newly emerged young of *Macrobdella decora;* slightly enlarged.

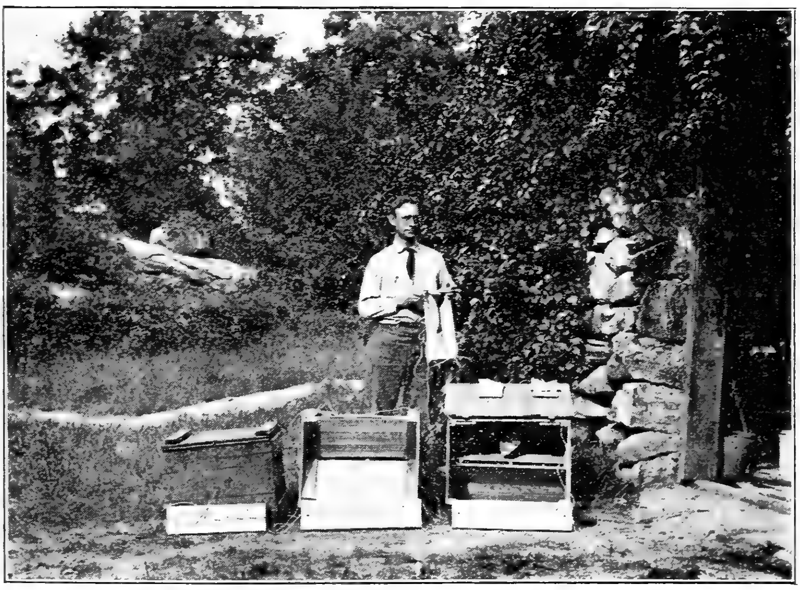

Fig. 15. Leech traps. Three views of box traps; showing from left to right, the top, front and interior from the rear; a canvas bait bag is shown in position above the slit-like entrance. The second type of trap is being held with the entrance forward.

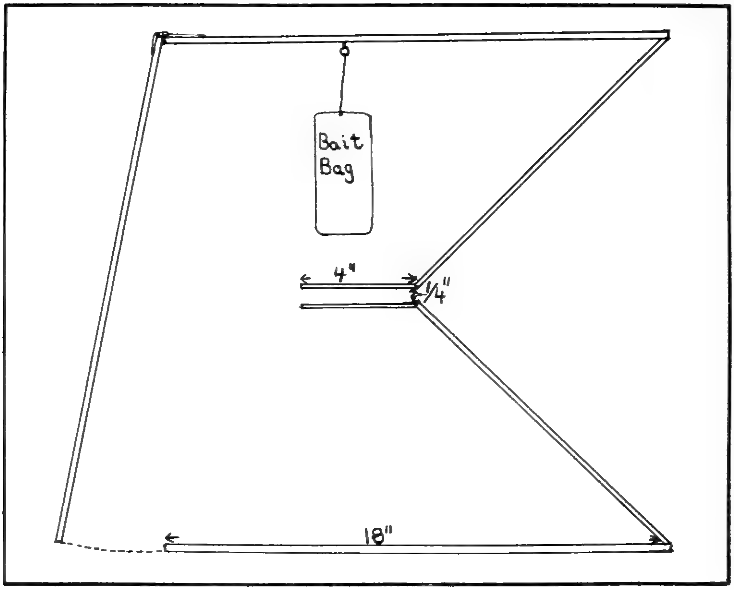

Fig. 16. Sectional diagram of box trap.

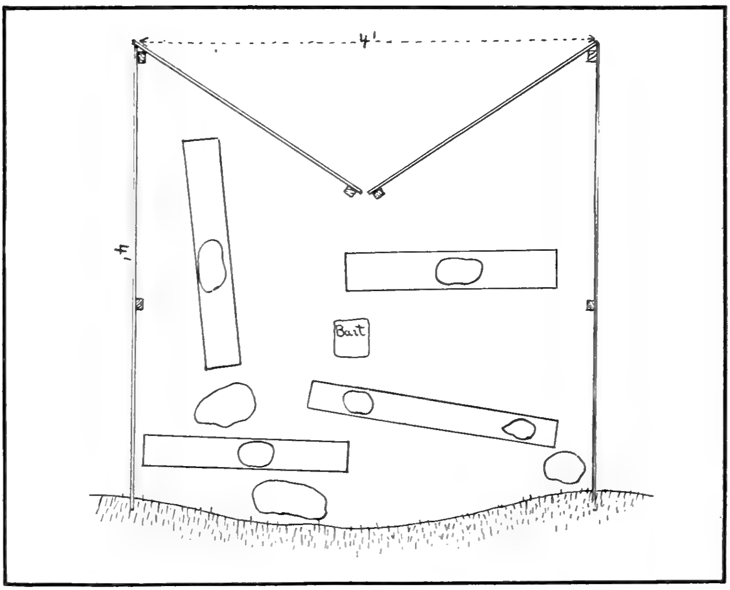

Fig. 17. Diagram of pen trap (third form), showing relation to bank, the entrance, position of bait, and boards and stones to afford concealment.

Use of Poisons and Repellents. That leeches are excessively sensitive to certain poisons is well known. For example, a trace of chloroform or nicotine placed in a vessel in which they are living will cause them almost immediately to fall to the bottom in a rigid moribund condition. The thought naturally arose, therefore, that a poison might be applied to the lake waters in doses lethal to the leeches without injury to the other inhabitants, or that, without killing them, the leeches might be repelled from the swimming places with the same facility with which they are attracted. It is quite probable that such a method could be worked out but there was time to experiment with a few substances only.

For several years it has been customary to treat the waters of Carr Pond and other lakes with copper sulphate to destroy the minute algae (water bloom) that otherwise would form extensive areas of surface scum to the annoyance of bathers. On a few occasions, when the application was made with insufficient care, large numbers of fishes were killed. It could not be learned, however, that there was any deleterious effect upon the leeches.

A series of tests was made to determine the reactions of the leeches to this salt. The experiments were made somewhat crudely as the facilities of the laboratory permitted nothing more refined; but the results are sufficiently accurate for the purposes in view though having no physiological value. A stock solution of one part of copper sulphate to nine hundred and ninety-nine parts of boiled and filtered lake water was prepared. This was diluted for each experiment to the desired strength with raw lake water. In each experiment from one to three freshly caught and active leeches were placed in each of three two-quart (sometimes one-quart) glass preserving jars. One was filled to the top with the fluid to be tested, so that when a cover of cheesecloth was tightly drawn across the top it became impossible for the leeches to avoid the solution. A second was exactly similar except that in place of the copper sulphate solution it was filled with untreated lake water like that in which the leeches normally live. The third was half-filled with the solution being tested, leaving a large air space above into which the leeches could escape from the poisonous solution. The three jars were placed together in a cool dark place and examined at intervals of usually one or two hours, when the condition of the animals, temperature, and other data were recorded. The dilutions ranged from 1 in 1,000,000 to 1 in 5,000,000 of copper sulphate and water and each experiment was repeated several times.

The results were very definite. In the jars containing the copper sulphate the leeches immediately showed signs of irritation and excitement. They swam or less often crawled with great activity, exploring all parts of the jars in their efforts to escape. In the full jars this activity continued for a long time or until the leeches appeared exhausted and fell to the bottom or hung relaxed from the side of the jar. In the half-filled jars they quickly discovered the air-filled upper half and came to rest usually with both suckers attached to the side and the pendant body well above the irritant liquid. In the check jars, after completing their explorations, they soon assumed normal resting attitudes.

Every strength of copper sulphate used proved lethal in time and every leech exposed to its full action died, except in two cases in which a 3,000,000 and a 5,000,000 dilution in which leeches had previously died, were used a second time. These had evidently lost their toxic properties through their previous reaction to organic substances. In the stronger solutions death (determined by the complete relaxation of the leech and its failure to respond at all when pinched with forceps) occurred in from five to twelve and one-half hours, in the one-five-millionth solution in from sixteen to eighty-six hours and in the intermediate strengths in corresponding periods of time. The variation in the time required by any particular strength to kill showed a rough correlation with temperature and amount of organic matter in the form of minute plant life present in the water, being negative to the former and positive to the latter; that is, the toxicity for the leeches increased with increase in temperature and diminished with increase in the quantity of minute algae present. The exact cause of death, whether due to the direct action of the metallic poison or to its indirect action by absorption of the dissolved oxygen in the water with consequent suffication, was not determined. Inasmuch as leeches are highly resistant to oxygen starvation it is probably not the latter.

In the half-filled jars the leeches continued to live through the period of the experiments. None seemed to be harmed in the least by the solution from contact with which they early escaped. In the check jars they lived normally, not a single one having died during the course of the experiments.

Concerning the effect of copper sulphate upon leeches in the lake itself I was fortunate to be present during two applications for water bloom. Though a very careful inspection of the shore was made not a single dead leech was found, although in one case the mortality among fishes and particularly among catfishes was considerable. Noticing that the water bloom in sheltered places close to shore, especially in shallow water, was often little harmed by the application of copper sulphate, it was thought that the poison might not have reached the leeches. To remove this doubt some of these places were sprayed with a one-five-thousandth solution. No effect on the leeches was noticed except that several were stimulated to activity, which might have been due to the fact that the operator in applying the solution often waded in the water.

It becomes clear, therefore, that copper sulphate cannot be used successfully to kill the leeches. If its use can be recommended at all, it is only as a possible repellent. If applied in considerable strength almost daily at the swimming docks it might drive the leeches away but its value for even this purpose is doubtful.

Because of its large use as a disinfectant for camp latrines, drains, etc., chloride of lime was selected for a similar series of experiments. It proved to be much less toxic than copper sulphate, the weakest solution that was lethal within four days being one-one-millionth and a few leeches survived this. A one-five-hundred-thousandth solution proved invariably fatal in from eighteen to forty hours. Chloride of lime seemed less irritating than copper sulphate but the leeches when free to do so avoided its effects in the same way.

Common salt was reported to have been used successfully to combat the leeches at one camp from which the most vigorous complaints emanated. Upon investigation it was learned that whenever leeches were caught they were laid on a board and nearly buried in granulated rock salt, which of course proved fatal. The camp directress was encouraged to experiment with placing a quantity of this substance in the crib in the hope of determining if the leeches could be repelled thereby. This was done in a casual manner without any record being kept of the quantity of salt used. I was unable to detect any reduction in the number of leeches.

Laboratory experiments showed that *Macrobdella decora* is highly resistant to sodium chloride solutions. When kept in solutions as strong as one per cent no apparent injury was noticeable after five days. In solutions of from .1 per cent to .02 per cent they exhibited increased activity for a short time (one to three hours) but after that appeared to be perfectly normal. In weaker solutions no effect whatever was apparent, and even in the strongest solution used there was no consistent attempt of the leeches to avoid it, such as was so obvious in the case of copper sulphate and calcium chloride.

Sulphuric acid was experimented with solely as an irritant and repellent. The subjects were placed in a blackened open vessel of water and allowed to assume resting attitudes. Measured quantities of the sulphuric acid solutions were then allowed to flow gently over various regions, generally the head, from the finely drawn out end of a medicine dropper. In each case an equal number of drops of pure water was applied with exactly the same precautions as a check, and the time, amplitude, and nature of the resulting reactions compared. The strengths of the solutions used ranged from 1.0 per cent to 0.1 per cent of concentrated acid (sp.gr. unknown). The leeches proved unpleasantly sensitive to all and exhibited avoiding reactions of varying moderate degrees of intensity. From the stronger solutions they quickly withdrew the head or portion of the body affected, turned directly away from the point of contact and either swam or crawled to the opposite side of the vessel where they remained. Even to these concentrations, however, the complete withdrawal would be characterized as leisurely, requiring from two to four seconds for its completion, though the initial contraction was instantaneous. To solutions of from 0.5 per cent to 0.2 per cent the first part of the response was similar but the leeches merely changed position and only very rarely left the spot. To the weakest solutions they behaved as they do to weak mechanical stimuli, such as a fine jet of water, the part touched being withdrawn without affecting the rest of the body and the original position being resumed after a brief interval.

Experiments with various other substances had been planned but the definiteness of the avoiding reactions of the leeches to the above seemed to sufficiently indicate their ability to escape the effects of any poison that could be safely used. For this reason, and partly because of the unfavorable weather conditions prevailing during the latter part of the summer, projected field experiments were not carried out. It is anticipated, however, that unless employed daily and in large quantity about the swimming places little practical results could be expected. It is probable that the best results could be had in the autumn when the water becomes cold and the leeches sluggish. The experiments with calcium chloride especially indicate that with lowered temperature the toxicity of the solution decreases less rapidly than the vigor and certainty of the avoiding reaction of the leeches. It seems probable, therefore, that at a temperature approaching that at which the leeches become very sluggish and their senses dull, a point might be reached at which poisons could be applied effectively. Experiments to determine this would be well worth while and if the expectation were justified the method would have the advantage of local applicability if desired.

Freezing in Winter Quarters. After full consideration of all of the possibilities suggested by the known life history and behavior of *Macrobdella decora* the conclusion was reached that under conditions existing at Carr Pond the most promising and practicable method of reducing the population of these leeches was offered by freezing them in their winter quarters. Accordingly the following memorandum of recommendations was prepared and forwarded to Mr. Edward F. Brown, Superintendent of the Camp Department:

" Several species of leeches inhabit the waters of Palisades Interstate Park. The one complained of by the bathers in Carr Pond is *Macrobdella decora,* a true blood-sucking leech. This species is moderately abundant in Carr Pond and less so in some of the other lakes. In considering methods for reducing and controlling its numbers almost every feature of its life history and behavior was passed in review and many experiments and observations made. These will be fully detailed in a complete report to be sent to Doctor Adams. All that is required here is to put in writing in a more formal way the plan for dealing with the leech nuisance in Carr Pond that was outlined verbally to Mr. Welch.

" Strictly speaking, like the frogs with which it so largely associates, this ' blood-sucker ' is a swamp animal rather than a pond animal. Its excursions into the open waters are chiefly in quest of food or new living places. Its home is in the shallows and along the shorelines. This fact was recognized in all of the plans for its control that were considered, and is in large part the basis of the one adopted for recommendation.

" Two other facts particularly influenced the formulation of this plan. As is true of many other lower animals the activity of leeches is largely determined by the temperature. As the temperature of the water falls with the onset of winter they become more and more sluggish and finally bury themselves in the mud or beneath stones on the bottom in shallow water. At 39° F., the point of the maximum density of water and the general winter temperature of pond water, they are dormant and nearly insensitive. They therefore hibernate in the mud until aroused to activity by the rising temperature of spring. In the vicinity of Philadelphia the great majority of them may be found during the winter occupying a zone between the depths of eighteen and thirty inches. Some go beyond these depths, but few or none into deep water. The advantages of this distribution is obvious. As the heavier cold water first accumulates and longest remains in the depths, animals of the physiological type of the leech must enjoy a longer season of activity because their winter quarters lie in the shallows. Because the ponds probably freeze to a somewhat greater depth in the New York Highlands than at Philadelphia we may expect that the leeches will occupy a correspondingly slightly greater depth.

"The remaining fact is that these leeches may be readily killed by exposure to a temperature of 20° F. for a few hours. These determinations were made in a small quantity of water and soft mud and upon leeches shortly before living in a state of activity at higher temperatures. Whether the same temperature would prove fatal to leeches naturally hibernating is not definitely known. They may be more resistant. Here is a source of possible but improbable error that experiment only will determine ([1]).

"The procedure recommended is as follows: About the beginning of December, when the first thin ice starts to form, when it is certain that the body of water in Carr Pond has attained its minimum temperature and that the leeches have become dormant, the water is to be drawn off as rapidly as possible until the level is lowered four feet. It is to be maintained at this depth continuously for at least five or six weeks during the coldest part of the winter, after which the headgates will be closed in time to impound the melted snow waters when the spring thaw comes. It is believed that a sufficient margin of safety has been provided to cover the two factors of uncertainty referred to above. Lowering the water level four feet should include the greater depth at which the leeches might be expected to winter at the more northern latitude. During the period chosen the occurrence of several spells of zero, or near zero, weather and nightly temperatures very generally below 20° F., may be expected. Under these circumstances the exposed flats should be frozen hard to a considerable depth and temperatures well below the fatal minimum reach the imprisoned leeches.

"The advantages of the plan are its simplicity, inexpensiveness, and the ease with which it can be applied at one operation to the entire lake. According to Mr. Welch it is feasible from the standpoint of operation and open to no objections from that of engineering.

[1] Experiments conducted at my home during the early part of the winter of 1919-20 determined that the minimum temperature lethal point is the same for leeches taken from a condition of dormancy as had been determined previously for active leeches, that is, it is the same whether the temperature has been lowered rather rapidly or very gradually. In either case before dying they become increasingly sluggish, quiescent and dormant and shrink in size, probably through the loss of water chiefly in the form of mucous and nephridial secretion.

Lowering the water level will damage no construction work and only slightly interfere with the winter use of the lake. There will be, of course, still a large surface from which to harvest ice, the cost of which will be only slightly increased by the greater distance over which it will have to be carried. No harm will be done through the loss of water, as the working level of the lake will be easily reestablished by the spring thaws. There are some collateral advantages, especially from the standpoint of mosquito control. The exposure and freezing of the flats should operate to destroy some of the undesirable vegetation. It would almost certainly destroy any larvae of that very troublesome mosquito, *Mansonia perturbans,* living about the lake. It would afford the best of opportunity for clearing up the lake shores and removing obstructions, etc.

" Some biological disadvantages must be noted. Various animals associated with the leeches on the flats would suffer with them. Doubtless large numbers of small frogs which abound in this lake and which winter similarly to the leeches would be killed. However, their lethal point to cold is somewhat lower than that of the leeches and they penetrate the mud to a greater depth, so that the percentage of mortality might be expected to be lower. Other species of leeches not included in the indictment against *Macrobdella decora,* such as the large *Hæmopis grandis,* would be equally affected. Many kinds of aquatic insects, worms, mollusks, etc., which serve as food for fishes would probably be killed. This important aspect of the matter was discussed at length with Dr. Adams, our conclusions being that too little is known of the winter condition of many of these organisms upon which to base a positive decision. Especially do we know little of the powers of resistance to cold of most specific organisms. The only thing to do is to try the experiment, the value of which would be very greatly enhanced were it possible to have a competent biologist on the ground to observe the effects. In general it may be stated that insects in their winter state are highly resistant to cold; that the chironomids, whose larvae constitute perhaps the most important single element in the food of small fishes, largely inhabit the aquatic vegetation and the bottom ooze at greater depths than those affected; and that the small entomostracan crustaceans, so important as food for young fishes and many organisms on which the larger fishes subsist, mostly produce winter eggs especially resistant to great cold and drought.

" It seems desirable to emphasize several considerations upon which the success of the plan will depend, and the ignoring of which may lead to its failure. It is very important that the water be not drawn off before the leeches have become fully dormant. In that case they would probably follow the receding water and take up winter quarters at a new and safe level. For the same reason the level should be reduced as rapidly as possible, and a time when much surface water is draining into the lake should be avoided. It is desirable that the flats should be exposed during a cold snap so that freezing will take place as rapidly as possible. If done during a warm sunshiny period the leeches may be stimulated to burrow more deeply into the mud, thus securing additional protection. A heavy fall of snow also might so blanket and protect the flats that the cold would be prevented from penetrating to the desired depth and degree."

(" Third Memorandum, September 14, 1919.")

In accordance with the foregoing recommendation the headgate at the lower dam of Carr Pond was opened at the end of November and the new level attained on December 6, 1919, concerning which Mr. W. A. Welch furnished the following data: At that time ice three inches thick completely covered the lake. That same night snow fell to a depth of two inches and on following days there were many successive snowfalls, so that the ground and surface of the lake were continuously covered. Drawing off of the water required about three days, by which time the level had been lowered two feet in the body of the lake and six feet in the lower extension below the old dam. The temporary dam was then blown out and the water level equalized. During the month of December the temperature had been continuously cold and several times had fallen to zero.

On December 30, I personally visited Carr Pond and noted the prevailing conditions. Measurements were taken at the dam, on a tree standing in the water at the extreme head of the lake, and on the docks at Globe, Jacob Riis, and Kennedy camps. At each of these points the level measured from the top of the solid ice was as nearly as could be ascertained two feet nine inches below the normal level of the preceding summer. Nearly all of the little bay or cove near Mr. Herbert's shack, and considerable areas of that at Globe Camp, together with a border of varying width around the shorelines, were drained. All such places were covered with a layer of hard ice about three (2.25 to 3.50) inches thick, evidently that existing at the time the water was drawn off and which settled down as the water level fell. On the lake generally the ice was from seven to eight and one-half inches thick and on this lay a covering of snow from eight to eleven inches thick, the latter at the cove near Herbert's shack and vicinity. The air temperature in the shade just before noon of December 30, a clear and calm day, was $-4°$ C. (25° F.).

Soundings made at various points around the lakeshore showed that in most places the ground beneath the snow and ice covering was frozen to a depth of only about two inches. Immediately beneath this crust the temperature was $+ 1°$ C. (34° F.), at four inches depth it was $+ 2°$ C. (36° F.) and at one foot $+ 4°$ C. (39° F.). That the failure of the cold to penetrate deeper was due chiefly to the protection of the snow blanket is indicated by the fact that the ground under cover of the dock floor at Globe Camp, which was free from snow, was frozen solidly to a depth of six and one-quarter inches. At the drained cove near Herbert's conditions were still less favorable. Here the snow was eleven inches deep, the ice only two and one-quarter inches thick and the underlying mud everywhere unfrozen and very generally of a temperature of $+ 4°$ C. (39° F.) even where in actual contact with the ice. An examination of the lower surface of the ice made it evident that after settling down into contact with the bottom mud, the higher temperature of the latter had been sufficient to melt it somewhat. This was shown not only by the fact that the ice here was about three-fourths of an inch thinner than on most parts of the drained bottom but also by the spongy texture and the impressions of leaves, twigs, etc., which characterized its lower surface. The bottom here, and to a less degree in other shallow coves and basins, is a nearly black muck filled with organic matter, the slow oxidation of which probably frees a perceptible quantity of heat. It was also determined, especially in the neighborhood of Globe and Brooklyn Industrial Camps that much ground water from both exposed and subaqueous springs was draining into these basins, the effect of which was to maintain a higher temperature of the bottom even after exposure.

Comparing the existing conditions with those postulated in the recommendation of September 14 it will be seen that the temperature of the bottom mud instead of being -6° C. (21° F.) as desired was about 10° C. (18° F.) warmer. While the air temperature had been sufficiently low to effect the desired result under favorable conditions it seems evident that three factors were operating to prevent it. First, the heavy and continuing blanket of snow acted as an insulator against the rapid radiation and conduction of ground heat; second, the effects of the cold were greatly mitigated by the constant and abundant flow of warmer ground water beneath the ice and snow cover; and, third, the slow decomposition of abundant organic matter in certain places freed sufficient heat to somewhat elevate the temperature. The effect of the first two conditions, if realized, were anticipated and referred to in the memorandum; the possibility of the third, though obvious enough, was overlooked.

Concerning possible remedies it is obvious that corrective measures on a scale sufficiently large to be of much value could scarcely be taken against conditions 1 and 3. For experimental purposes it would be practicable to keep limited areas free of snow, especially by the use of a horse plow on the coves at Globe Camp and Herbert's. But the effects of 2 might be mitigated by further lowering the water level. This would expose a larger surface of the bottom to loss of heat, drain off the warmer ground waters from the flats more effectually, and remove the wintering areas of the greater number of the leeches farther from the tempering influence of the body of water of the lake. Accordingly, it was recommended to Mr. Welch that the water be lowered an additional eighteen inches as soon as practicable. This would bring it to a point three inches lower than had been proposed originally.

The search for the leeches in their winter quarters was handicapped by the heavy covering of snow and ice, but thanks to the efforts of two men furnished by Mr. Welch a quantity of the mud from the bottom of the Cove near Herbert's was shoveled on to the ice and examined. Two leeches only were found, one each of *Macrobdella decora* and *Erpobdella punctata*, both alive and dormant.

The winter of 1919–20 proved to be a long and severe one, with the temperature continuously moderately low. So far conditions were favorable to the success of the experiment. On the other hand the snowfall was remarkably heavy, so heavy, indeed, that it prevented the taking of the supplementary steps recommended. In reply to an inquiry Mr. Welch wrote me under date of March 8, 1920: "Shortly after your visit here we had so much snow that we had to abandon all work in the Park this winter; the roads are all closed and it has been and is still impossible to get around at all. There are approximately seven feet of snow in the mountains now." It is much to be regretted that conditions proved such as to leave the results of the experiment in doubt. The following data were furnished by Mr. Welch from his office records: The ice on the lake attained a thickness of fourteen inches and the snow of twelve inches, both remaining throughout the winter. The temperature frequently reached $-5°$ F. and remained continuously low until the latter part of March. The normal water level in the lake was reached on March twentieth.

Owing to various circumstances I was unable to visit Carr Pond again until August 2, 1920, during which week several days were spent in attempts to determine whether the blood-sucking leeches had been noticeably affected by the conditions existing at the pond during the winter. Two lines of inquiry were carried out, as follows:

First: all of the camp directors and others who were in a position to know were requested to express an opinion concerning the relative abundance and troublesomeness of the leeches during the summer of 1920 compared with that of 1919. Later, Mr. Brown made the same inquiry independently in the form of a questionaire. The following table shows the results:

NAME OF CAMP	Leeches more or less numerous in 1920 than in 1919	Average number of campers bitten per day in 1920	Remarks
Brooklyn Industrial	Less	About 2	Boys do not mind them. Used for bait.
Globe	Less	1 or 2	Used for bait.
Jacob Riis and Trinity	Much less		Site occupied by Trinity Camp in 1920.
Kennedy House	Much less	Not over 1	During 1919 this camp was always a prolific source of supply.
Big Brother	Less	About 2 per week.	Many leeches caught by the boys both summers.
Hebrew Orphan Asylum, Boys Branch.	More	About 2 or 3	Used for bait. Two or three times as many and larger than in 1919.
Nathan Hale	More	Not over 1.	
Martha Barbour	Somewhat more	1 or 2	Always troublesome. Girls camp.
Greenwich	About the same	About 5 per week.	Boys catch about 6 or 8 per day.
Ramapo	Much more	2 or 3	Six to twelve caught daily.
Girls Patriotic League and Brooklyn Girls.	More	Usually 1 or 2.	About six caught per day.

The first four camps listed are situated on the old part of the lake, the next three are just within the extension and the remaining four are well within the latter. The table includes only those camps concerning which unequivocal data covering both years are available and upon which the information furnished to Mr. Brown and myself agreed. The data from other camps is confirmatory, so far as they go. Mr. Herbert expressed the opinion that there were fewer leeches in 1920 than in 1919, and in 1919 than in 1918. In reply to an inquiry Mr. Welch wrote on November 30: "From all appearances there were as many leeches in Carr Pond during the summer of 1920 as there were during the summer of 1919," and on December eleventh: "All of the information which I have been able to gather seems to show that last year the leeches had certainly moved from their former locations and were more prevalent in new sections of the lake and it had occurred to me that this might be due to the fact that when we drew down the waters of this lake the new emptied very much more rapidly than the old and the leeches left in the mud in this section were able to get out and down to the water before the final freeze up."

Second: a personal examination similar to that conducted last summer to determine the abundance and distribution of the leeches was made. While this, of course, does not furnish an accurate census it does give a basis for rough quantitative comparison. In 1919, twelve stations, representing a variety of conditions and different parts of the lake shore, were selected for careful examination. So far as practicable these were of approximately equal size, that is, each was a section of the shore about fifteen feet long and three feet wide, one foot of the width being landward and two feet in the water. The several areas were not accurately measured but only paced off. The general physical and biological conditions were noted. All pieces of timber, sticks, stones or other objects affording places of concealment were lifted and scrutinized and the mud and turf more or less probed and superficially examined.

All leeches taken within the marked areas were counted, but the figures for *Macrobdella* only are given in the table. The attempt was not to make the determination quite exhaustive of all the leeches present in each area as this would have involved washing and screening the soil to a depth of three or four inches, but nearly all were secured by the method adopted. In 1919 each station was examined several times during the summer and the figures given show that later examinations invariably yielded a much smaller number of the larger leeches. In 1920 the time was sufficient to examine only six of these stations with the same thoroughness as in 1919. The others were examined much more hastily but so far as they go the figures are confirmatory.

TABLE showing number of *Macrobdella decora* collected or seen at selected stations (figure 3). Numbers 8 to 11 are on the new part, the others on the old part of the lake. Note that in 1919 the number decreases with the progress of the season at every station but number 11, though this is less marked at stations close to swimming docks, as numbers 3, 7 and 12. X, means no or incomplete collections made.

NUMBER AND LOCATION OF STATION	DATES OF COLLECTIONS IN 1919							Aug. 4 and 5 1920
	July 5	July 8	July 14 and 15	Aug. 1 and 2	Aug. 9 and 11	Aug. 21 and 23	Average 1919	
1. Island opposite Globe Camp	*23	x	13	18	11	9	14.8	8
2. Head of cove north of Globe Camp	x	8	7	8	7	4	6.8	x
3. Head of cove south of Brooklyn Industrial Camp	6	x	7	4	2	5	4.8	x
4. Site of former sawmill, south end	18	x	10	11	8	8	11.	7
5. Head of cove south of Herbert's shack	12	x	9	7	8	9	9.	8
6. Point north of Herbert's shack	4	x	5	6	3	3	4.2	x
7. Shallow at Kennedy House Camp	19	x	14	14	11	13	14.2	6
8. Shallow between the Negro (Ideal) and Ramapo Camps	x	8	8	8	5	4	6.6	x
9. West shore near dam. This area was practically all water	6	x	4	1	3	0	2.4	7
10. Pool at foot of dam	x	2	4	0	x	x	2.	x
11. Foot of Nathan Hale Camp. Proximity of bathing beach	x	6	7	7	6	8	6.8	12
12. North of Jacob Riis Camp. Trinity Camp 1920, near crib	x	7	9	9	8	3	7.2	x

* Some boys from Globe Camp assisted in making this collection.

Stations (especially Nos. 1, 4 and 7) on the old part of the lake all show a very marked diminution in the number of *Macrobdella* collected. These also are the points where this species was most abundant in the summer of 1919. Possibly the fact that the first collections recorded for 1919 were made between two and three weeks earlier in the season may have exaggerated the divergence but later collections made early in August (either the first or second) of 1919, within two or three days of the 1920 dates, give figures still in excess of the latter (except for station 7), namely, 18, 11, 7 and 14 respectively for these same stations. Stations 9 and 11 are representative of conditions on the new part of the lake and both exhibit marked increases.

Less thorough examinations and collections were made at many other points and generally in the old part, and in nearly every case in the newer part of the lake the results proved consistent with the above figures, namely, they indicate that these leeches have diminished in numbers in the old lake and increased in the extension. In this connection it should be recalled that all of the observations made during the summer of 1919 demonstrated just the reverse, the leeches being much more plentiful in the body of the lake above the old dam than below it. This was attributed to their not having yet migrated in large numbers into the newly filled lower end of the lake. Sometime during the interval between the two examinations this redistribution has taken place. Nevertheless, in 1920 they had failed to attain in the new part of the lake their abundance of the preceding year in the old part. Their distribution had become much more uniform but the population was nowhere so dense as in the most populous places in 1919.

If these rather meagre though consistent data can be relied upon it appears clear that the total population of *Macrobdella* in Carr Pond has been considerably reduced, for not only do the figures indicate that the ratio of decrease in the old part exceeds that of increase in the new part of the lake but it must be remembered that the area involved in the former is about four and one-third times that involved in the latter condition. How much of this decrease may rightly be attributed to the effects of the experiment and how much to other conditions it is impossible to know, inasmuch as, unfortunately, no definite checks could be made available. It may be pointed out, however, that the differences in hydrography of the two parts of the lake is consistent with a greater destructive effect of freezing in the old than in the new section. In the former is found more of gently shelving beach and large areas of shallow. The lowering of the water level exposed some fairly extensive flats upon which the wintering leeches must have found it difficult to escape the effects of the cold. On the other hand most of the new part of the lake has a trough-like form with the bottom in most places sloping rapidly into deep water. Not only would this conformation retard the chilling process but it would facilitate the escape of the leeches from its effects. The removal of the old dam, permitting of a freer circulation of the water and doubtless of a freer interchange of life also, doubtless facilitated the migration and equalization of the leeches in the two parts of the lake.

The time was insufficient for any careful determination of the relative abundance of other life associated with the leeches during the two summers. But I was strongly impressed that frogs were much less plentiful in 1920 than in 1919. This seemed especially so on the shallows near Globe and Brooklyn Industrial Camps. At all points around the shore except one area near the dam the marginal vegetation was obviously less luxuriant than in 1919.

In view of the facts and opinions recorded in the foregoing account it was very desirable that the experiment be repeated. Consequently in a letter to Mr. Welch, under date of August 18, the following paragraph was written: " It seems to me that the results are sufficiently encouraging to warrant a continuance of the experiment and I recommend that the water be again lowered during the coming winter with the same precautions emphasized in my memorandum of last year, and in addition that the degree of lowering be made six feet instead of four. This will have the effect of draining off the warm ground waters more completely and at the same time make it more difficult for leeches wintering on the borders of the area to escape."

Owing to the mildness of the winter of 1920–21 and especially to the paucity of the snowfall Major Welch declined to draw off the water, fearing that the spring run-off might prove insufficient to reestablish the old level.

During 1921–22 conditions proved much more favorable for a repetition of the experiment and under date of May 29, 1922, Major Welch wrote: "When the first freeze [of the preceding winter] came the lake was full and we immediately drew it down. Within two or three days the water had lowered about four feet and just after this we had a period of very severe weather which froze the ground very thoroughly before the snow came. Of course, it is too early in the season to say what the result has been and as soon as we have an opportunity to observe, I will be very glad to give you all the facts."

On September 14, 1922, Major Welch wrote further: "I am very glad to be able to inform you that the leeches have not been in evidence at Lake Stahahe this year. I am not sure that they have all been destroyed although I have been unable to find any nor can I get any reports from the camp directors on this lake which lead me to believe that they have found any. If we have a good opportunity this winter to again lower Lake Stahahe and freeze the mud over its shallow areas we shall do so in an endeavor to entirely eliminate these leeches."

This statement of Major Welch is confirmed by Miss R. M. Joliffe, Mr. E. F. Brown's successor as Superintendent of the Camp Department who writes (Nov. 3, 1922): "We had no trouble so far as I know with leeches in Lake Stahahe last summer;" and by the direct testimony of camp directors, twelve out of fifteen of whom replied to a questionaire.

Two directors report leeches more numerous in 1922 than in 1921, one adding that they had decreased in number from 1919 to 1921, four that they were less numerous and five much less numerous in 1922, while one fails to answer this question. Answering the question how many campers were known to have been bitten during the season, six reply none, three one, one two, and two eight or ten. It is rather interesting that both of those directors who reported leeches as more numerous in 1922 also state that none of their campers were bitten during the season and one adds that very few were seen all summer. Most of the directors state that few or even no leeches were seen and the two highest estimates of the number seen are about five daily and twenty-five for all summer.

These camps are located all around the lake and more than half of them are very near to census stations at which the leech population was counted in 1919 and 1920. The two camps where an increase was reported are both located at the south end of the lake. One of the most significant statements is that of Mr. Wm. Demerest, of

Kennedy House Camp, who has been on the lake for many seasons and is very familiar with conditions. He says: "We seemed to be absolutely free of leeches at our place." My station 7 was located at this camp and blood-sucking leeches were more plentiful there than at any other point on the lake. At every visit during the summer of 1919 leeches were found and the campers almost always had a large number that they had captured for me.

The evidence seems unequivocal, therefore, that there has been a great decrease in the number of these leeches since the summer of 1919 during the progress of these freezing experiments. While it cannot be said that the relation of cause and effect have been fully established this probability seems sufficiently great to warrant the recommendation of the method for the control of blood-sucking leeches under conditions similar to those in Palisades Park: namely, in bodies of water the level of which can be rapidly lowered, in which there are shallow areas, and which are located in regions climatically favorable. Just how far the method may be successfully applied remains to be determined experimentally.

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PRELIMINARY REPORT ON THE PARASITIC WORMS OF ONEIDA LAKE, NEW YORK.

By Dr. Henry S. Pratt.

Professor of Biology, Haverford College, Haverford, Pa.

CONTENTS

INTRODUCTION

The author of this preliminary report, assisted by Mr. Frank C. Baker, at that time zoological investigator at the State College of Forestry and at present Curator of the Natural History Museum of the University of Illinois, began on August 21, 1917, a study of the parasitic worms infesting the fish and other aquatic vertebrates and the mollusks of Oneida Lake, New York. This study was conducted under the auspices of The New York State College of Forestry at Syracuse and the United States Bureau of Fisheries, and under the immediate direction of Dr. Charles C. Adams of the College of Forestry, as a part of a general ecological and fish cultural survey of the inland waters of the State. The general plan of the work is as follows. First, as complete collections as possible are to be made of the parasitic worms infesting the aquatic animals in the lake; and second, an intensive study of the parasitic worms of the different species of the important fishes of the lake is to be made, with a view to learning as much as possible of the life history of these parasites. The present paper gives an account of the first collections made in accordance with this plan, in the late summer of 1917. The further collections being made from time to time will doubtless add to the number of species of fish and other animals, and to the list of parasitic forms harbored by these creatures.

NATURE OF AQUATIC PARASITIC WORMS

The parasitic worms that infest fishes and other more or less aquatic vertebrates, as well as fresh-water mollusks, belong to four general groups: the Trematodes or flukes, the Cestodes or tapeworms, the Nematodes or threadworms, and the Acanthocephala or spiny-headed worms. All of these worms, with the exception of a few species of flukes, are internal parasites, living in the various internal organs of the host — as the animal is called which harbors a parasite. When they occur in large numbers in a vital organ they may seriously affect the health of the host, and either cause its death or form such a brake on its locomotor activities that it falls an easy prey to its natural enemies.

As a rule parasitic worms are in a high degree selective in their choice of the host and also of the particular organ in which they shall pass their existence. A species of parasite which lives and breeds in a fish could not pass the same stage of its life history in a frog or in any of the land vertebrates, and usually a parasite that is found in a given species of fish would be found only in that species, or at least in some closely allied one. Also, a species of worm that normally inhabits some particular organ of its host will usually not be found in any other organ. If it lives in the mouth, for instance, it will not, as a rule, occur in the intestine, and a worm which may be looked for in the duodenum will not be found in the rectum. A worm that attaches itself to the gills and sucks the blood of the host in that favored locality will never be found in the interior of the body.

It is not intended, however, to give the impression that a worm consciously seeks the particular host and organ in which it will flourish best. In the course of the evolutionary history of these worms, as indeed in that of all animals, each species has, as the result of the operation of natural selection, become adapted to a certain more or less definite environment where it finds the conditions of existence favorable. Internal parasites are bound to a specific environment more rigidly than perhaps any other animals, because, living as they do within the body of their host and confined to a narrow space, they are constantly immersed in its body fluids. The chemical and physiological action of these fluids, to which the entire organization of the parasite is thus adapted, varies radically in different localities of the host's body, and a species of worm whose relation to its host would fit it for a prosperous existence in one organ might not be able to exist at all in some other, or perhaps in any other. A parasite, for instance, which clings to the mucous membrane of the mouth or pharynx of a bird, where the reaction of the salivary juices is an alkaline one, would not survive if it should be carried into the stomach, where the reaction is an acid one, but would be digested like any other particle of organic matter.

It is, in fact, hardly possible to exaggerate the extreme delicacy of the adjustment of an internal parasite to its environment, which binds the parasite in most cases to a certain organ of a certain host-animal. It is thus important in studying internal parasites to observe carefully the localities in the host's body in which the parasites are found, and all the accompanying circumstances of their life and surroundings. Quantitative studies of these points are also important, since the greater the number of observations the truer will be the generalizations based upon them. One of the main objects of this whole study is to determine these conditions and thus to throw light upon the life history of the parasites under investigation.

The life history of most internal parasites, however, includes much more than their life in the hosts in which they pass their adult existence. There are in most cases two distinct periods in the life of such animals, (1) the adult period, and (2) the larval period. In the first period the parasite lives in some one of the open organs of the host, which has direct communication with the outer world, such as the digestive tract or the lungs. Here the parasite reproduces itself, and from its seat its eggs or young find their way to the outside, usually with the dejecta of the host. In the larval period the young animal, having thus been carried to the outer world, lives for a while a free, non-parasitic life, and is later transferred either directly to a host similar to the parental host, in which it is destined to pass its adult, parasitic existence, or to a host very different from the parental host, in which it passes into a second larval stage. In the latter case the young worm leads a more or less inactive life, often enclosed in a cyst, until this host is finally eaten by an animal of the same, or in some cases of a nearly related species, as the parental host. The young worm is thus mechanically transferred to the stomach of this animal and in the course of time makes its way into that particular organ in which nature has intended it shall live and breed.

It will be seen from this statement how complex is the life history of parasitic worms, and how necessary are intensive studies of them and their several hosts. It is not sufficient to collect the adult worms and to study their relation to their hosts, the larval worms and their hosts must also be studied in order to complete the life-cycle; and until the life-cycle is understood it is often impossible to suggest a means of controlling the ravages of the parasite. It is just for this reason that field studies like those being made on the shores of Oneida Lake are important, where the conditions are unusually favorable for investigating every phase of the life history of the parasites under consideration.

The organs of the host animal which are most liable to be infested by parasitic worms are the different portions and appendages of the digestive tract, and all the divisions of this tract from the mouth to the vent may harbor them. It is unusual to find a fish or other aquatic vertebrate that does not have these worms in some or every part of this tract. In most cases, however, the number of worms in a single intestine is not large, but occasionally cases of heavy infestation are found. One large water snake was found on the shores of Oneida Lake the stomach of which was literally packed with large Nematode worms, so that it was difficult to see where there would be room for the animal's food. Two eels, also, were found with their intestines so distended by the tapeworms they contained that the vitality of the fish must have been seriously lowered. The practical reason why the digestive tract is a usual place of infection of adult parasites is that they are usually brought into the body of the host with its food.

After the digestive tract, perhaps the most frequently infected organs are the respiratory organs. In fish the gills are a favorable location for numerous species of flukes, which attach themselves to the gill-filaments and suck the blood of the fish through their delicate walls. A heavy infection of this sort might easily result in such a serious loss of blood by the fish that it would languish and die. The lungs of frogs almost always contain flukes that sometimes quite fill them. The air-passages and lungs of birds, turtles, snakes, and other aquatic vertebrates are also often infected.

All parasitic worms have very great reproductive powers, and when the conditions accompanying their embryonic and larval development are unusually favorable, as occasionally happens, they may increase in number to such an extent that a parasitic epidemic follows and thousands of animals of the species affected may die. Such epidemics occur among fish from time to time, and are sometimes familiar to fishermen because of the large number of dead fish they find strewn along the beach. Where the fish which are thus destroyed belong to species having commercial importance it is evident that the economic loss may be great.

Where an animal is but slightly infected with animal parasites they may not apparently affect its health or general well-being, but it is probable that any considerable infection, while not perhaps sufficient to affect the activities of the host, would reduce its reproductive powers and prevent it from bringing into the world the normal number of young. Parasitic castration, more or less complete, is a matter of considerable importance in the animal world, and has been frequently observed among Crustacea and other invertebrates. The parasitized animal may be affected either by the destruction of the tissue of the sex glands by the parasites, or by being so weakened by them during its developmental period of life that the sex glands fail to develop or to function normally, and the animal's mating instincts remain inactive. It is probable that in the case of fish and other vertebrates the effect of parasitism on reproduction is similar. Definite information, however, is lacking, and observations directed to the matter would be of great value.

Parasites sometimes affect the commercial value of food fishes even when apparently they have no influence upon their health or their ordinary habits of life. Perch, rock bass, sunfish and other food fish in Oneida Lake are frequently caught, especially in the late summer and fall, in which good sized cysts are found imbedded in the muscles, often just beneath the skin, in the gills, fins or in other parts usually more or less superficial. Each of these cysts contains a Trematode worm ranging from 4 to 10 mm. in length, and is usually very noticeable. Although the worms are entirely harmless to man, and would simply be digested with the flesh of the fish if eaten, wormy fish are usually thrown away by fishermen and cannot be sold in the market. A popular account of the relation of the worm parasites to fishes and the influence of these parasites on their food value has been published as a part of the present study, as: Parasites of Fresh-water Fishes, U. S. Bur. Fisheries, Econ. Cir. No. 42, pp. 1-8, 1919.

Many other species of fish also may harbor cysts containing larval Trematodes, Cestodes or Nematodes in their muscles and thus lose a part or all of their commercial value.

Of the four classes of vermian parasites that infest fish and other aquatic vertebrates perhaps the most important from an economic standpoint are the Nematodes and the Acanthocephala. These worms are slender, cylindrical animals, ranging from microscopic size to several centimeters in length, which sometimes infest their hosts in such large numbers that they either kill them outright or reduce their strength and vitality sufficiently to place them at a fatal disadvantage in the struggle for existence. The Nematodes, or threadworms, are usually found either in the digestive tract or in cysts embedded in the muscles or fat or attached to the peritoneum or to a mesentery. In the former case the worms are active adults, which usually range more or less freely in the portion of the digestive tract in which they live, sucking the blood or absorbing the vital fluids of the host and producing their eggs or young. They undoubtedly often injure the host by lacerating the intestinal wall and draining its vitality, and perhaps also by enabling bacterial or protozoan parasites to gain a foothold in its tissues and blood. The hookworm, which has in the past few years obtained such an unpleasant notoriety in the Southern States of this country, belongs to this group of parasitic worms.

Encysted threadworms are in their larval stage of development, and in this condition they lie dormant and inactive in their hosts without apparently doing them any harm. The cysts, however, like those of the flukes already mentioned, often affect the market value and sale of food fish, as purchasers of fish in a fish market will not usually buy fish which they see to be wormy, even when the worms are harmless, as they always are, and do not decrease the food value of the fish.

The Acanthocephala or spiny-headed worms live in the intestines of their hosts and are often very numerous in aquatic vertebrates. They resemble threadworms in appearance but differ from them, among other things, in possessing a prominent, more or less retractile projection, the so-called proboscis, at the anterior end of the body, which is covered with recurved hooks by means of which they attach themselves to the intestinal wall of the host. When they infect an intestine in large numbers, as they frequently do, the laceration of the intestinal wall by their spiny proboscides undoubtedly causes a severe injury to the host and may cause its death.

The Cestodes or tapeworms are very important parasites of aquatic vertebrates. The adult worm lives in the intestines of its host; the larval worm may be found in almost any organ of the body and in the body cavity, usually enclosed in a cyst, but in the case of certain species not encysted. Tapeworms are much the largest vermian parasites of aquatic vertebrates, some of them measuring 30 cm. or more in length, and are often fatal to fish containing them. The cysts are sometimes very common objects in the flesh of many of the smaller food fishes.

The Trematodes or flukes are probably the least harmful of the internal vermian parasites of aquatic vertebrates. The worms are of small size, usually measuring a few millimeters in length, and in most cases are not found in large numbers in a single organ of the host.

Occasionally, however, as already stated, they may infect the gills of a fish in large enough numbers to injure the animal. Not long ago such a species of fluke was discovered on the gills of the rainbow trout in the State Fish Hatchery at Cold Spring Harbor, Long Island. Practically all the trout a year or more old were infected, in many instances in such large numbers that the gills were shrivelled and functionless.

The larval stage of the Trematodes of fish and other aquatic vertebrates is passed very generally in snails, but also, in the case of certain species, in small fish, in crustaceans, and in other small animals that are the natural prey of the host of the adult worms. It is thus necessary in endeavoring to elucidate the life history of these worms to investigate these animals, especially the fresh-water snails. The study of larval Trematodes has been neglected in this country and observations made on their structure, habits of life, and their relation to their hosts, such as can be made with great advantage at Oneida Lake, will be of great value.

None of the worms that parasitize fishes and other aquatic vertebrates will live in the human body, with a single exception, which is, however, of such rare occurence in America as to be practically negligible. There need be no alarm, consequently, about the possibility of an infection of parasitic worms as the result of eating the flesh of any fishes, frogs, wild ducks or other similar animals. The exception just mentioned is the broad tapeworm *Diphyllobothrium latum,* which in its adult stage is a common human parasite among the Scandinavian peoples and other fish-eating populations of Europe, and in its larval stage lives in many species of food fishes.

TABULATED RESULTS

The following tables show the names of the species of fish, birds, reptiles, amphibians and mollusks that have been examined in the course of this study, the number of individuals of each species examined, and the number of parasites obtained from each species. Where the parasites were found in large numbers in an organ the number given in the table is usually an estimate, as it was often impossible to count them. This was especially true in the case of the Trematode and tapeworm cysts imbedded in the liver and the fat of the mesenteries of certain fish, such as the common bullhead, the bluegill, and the sunfish. In the case of the eels mentioned, but two complete fish were examined. Only the viscera of the others were examined, obtained from a fish dealer. The lists are not complete, as they record the results of but four weeks' work, and will be added to by future collections. They do, however, indicate the distribution of vermian parasites in Oneida Lake animals.

The animals were collected at or near the town of Brewerton at the western end of the lake, both in the lake itself and in the Oneida River, which is the outlet of the lake. A laboratory equipped with the necessary apparatus and instruments from the zoological laboratory of the College of Forestry was established at this place. The fish and other vertebrates examined were identified by Frank C. Baker and T. L. Hankinson; the mollusks by Frank C. Baker.

Fish Examined		Parasites Collected					
SCIENTIFIC NAME	Common name	Number examined	Number infected	Nematodes	Acanthocephala	Cestodes	Trematodes
Abramis chrysoleucas (Mitchill)	Golden Shiner	2	1	0	12	0	0
Ambloplites rupestris (Raf.)	Rock Bass	4	4	8	9	0	1
Ameiurus natalis (Le Sueur)	Yellow Bullhead	3	3	8	2	2 and many cysts	0
Ameiurus nebulosus (Le Sueur)	Common Bullhead	6	6	6	5	20 and many cysts.	17
Anguilla rostrata (Le Sueur)	Eel	39	39	7	20	36	40
Cyprinus carpio Linn	Carp	3	1	4	0	0	0
Esox reticulatus Le Sueur	Chain Pickerel	4	3	0	6	18	2
Eupomotis gibbosus (Linn.)	Common Sunfish	5	5	6	0	Many cysts.	9
Lepomis incisor (Cuv. et Val.)	Bluegill	2	2	0	0	0	Many cysts.
Micropterus salmoides (Lacépède)	Large-mouthed Black Bass	1	1	0	5	0	10
Micropterus dolomieu Lacépède	Small-mouthed Black Bass	4	4	0	22	Many cysts.	50
Erimyzon sucetta oblongus (Mitchill)	Chub Sucker	1	1	0	1	1	0
Perca flavescens (Mitchill)	Perch	8	8	13	0	0	5 and a few cysts.
Pomoxis sparoides (Lacépède)	Calico Bass	2	1	0	1	0	0
Stizostedion vitreum (Mitchill)	Wall-eyed Pike	9	8	0	70	27	1

Birds, Reptiles and Frogs Examined		Parasites Collected					
SCIENTIFIC NAME	Common name	Number examined	Number infected	Nematodes	Acanthocephala	Cestodes	Trematodes
Ardea herodias Linn	Great Blue Heron	4	4	0	0	Many	Many
Ardea virescens (Linn.)	Green Heron	2	2	13	0	1	0
Ceryle alcyon (Linn.)	Kingfisher	2	0	0	0	0	0
Larus argentatus Brünnich	Herring Gull	2	1	0	0	0	20
Chrysemys marginata (Agassiz)	Painted Turtle	1	1	20	0	0	0
Natrix sipedon (Linn.)	Water Snake	9	7	Many	6	20	12
Rana pipiens Schreber	Leopard Frog	12	11	Many	0	0	90

Mollusks Examined	Parasites Collected				
	Number examined	Number infected	Annelida (Chaetogaster)	Larval Trematodes	Hydrachnids
Anodonta cataracta Say	3	0	0	0	0
Anodonta implicata Say	1	0	0	0	0
Lampsilis luteola (Lamarck)	4	4	0	0	Few
Lampsilis radiata (Gmelin)	2	0	0	0	0
Sphaerium vermontanum Prime	2	0	0	0	0
Unio complanatus (Dillwyn)	2	0	0	0	0
Amnicola limosa (Say)	20	0	0	0	0
Ancylus parallelus Haldeman	1	0	0	0	0
Bythinia tentaculata (Linn.)	17	0	0	0	0
Campeloma integrum (Say)	3	2	0	Few	0
Goniobasis livescens (Menke)	23	6	0	Many	0
Lymnaea catascopium Say	10	6	0	Many	0
Lymnaea columella Say	1	0	0	0	0
Lymnaea emarginata Say	5	3	0	Many	0
Lymnaea haldermani Binney	10	0	0	0	0
Lymnaea palustris (O. F. Müller)	10	6	Few	Many	0
Lymnaea stagnalis lilliana Baker	18	10	15	0	0
Physa warreniana Lea	13	6	8	Many	0
Planorbis antrosus Conrad	13	2	1	Many	0
Planorbis campanulatus Say	25	6	6	Many	0
Planorbis hirsutus Gould	10	0	0	0	0
Planorbis parvus Say	3	0	0	0	0
Planorbis trivolvis Say	9	3	8	0	0
Valvata tricarinata (Say)	35	0	0	0	0
Vivipera contectoides Binney	3	0	0	0	0

DETAILED RESULTS OF THE INVESTIGATION

The following notes give in detail the results of the examination of the internal parasites found in (1) the fish, (2) the birds, reptiles and frogs, and (3) the mollusks mentioned in these tables.

Parasites of Fishes. *Abramis chrysoleucas* (Mitchill): Golden Shiner. Two fish were examined, in one of which no parasites were found. In the intestines of the other (No. 1219) were taken many Acanthocephala (Vial 31) belonging to the genus *Pomphorhynchus*. The worms were about 8 mm. long and were light brown or orange in color. But one species of this genus has been described from American fishes; two species are known in Europe which infect several species of fresh-water fishes. No Nematodes, Cestodes or Trematodes were taken.

Ambloplites rupestris (Raf.): Rock Bass. All of the four individuals examined (No. 1205f) were relatively little infected with internal parasites. A single Trematode belonging to the species *Crepidastomum cornutum* (Osborn) was found in the stomach of one of them. This worm has been taken before in the rock bass and several other species of common fresh-water fish in Canada and the eastern United States, and is undoubtedly a widely distributed parasite. Crayfish and may-fly nymphs (*Hexagenia*) are believed to be its intermediate hosts and numbers of both these animals were found in the stomachs of the rock bass examined (Nos. 1201, 1202, 1232). The same species of Trematode was also taken, and in large numbers, in the small-mouthed black bass from Oneida Lake.

Two of the rock bass examined contained Nematodes, belonging to two species. In one of them, three slender worms measuring each about 30 mm. in length were taken from the hinder portion of the rectum. These worms possess the oral armature which characterizes the genus *Camallanus* and are to be referred to the species *C. oxycephalus* (Ward and Magath). They were all females and the uterus contained young worms. The blood of this species is bright red and surges regularly between the two ends of the body, the blood-wave passing from the anterior to the posterior end and back again about six times in a minute.

The intestines of another fish contained five specimens of another species of Nematode, the largest of which was about 20 mm. long and the smallest about half that length. They belong to the family Cucullanidae and are to be referred to the genus *Dactinoides*. A species of this genus has been described from the perch and the wall-eyed pike in Lake St. Clair and also has been found in the perch in Oneida Lake.

The intestine of one of the rock bass examined contained nine Acanthocephala (Vial 79). The worms ranged from 6 to 12 mm. in length and belong to the genus *Echinorhynchus*, a genus containing many species parasitic in fresh-water fish.

No Cestodes were taken in the rock bass examined.

Ameiurus natalis (Le Sueur): Yellow Bullhead. Three fish (No. 1240, *1247A) were examined and but few parasitic worms were found, although all the fish were infected. In the intestines of one bullhead two Cestodes belonging to the genus *Corallobothrium* were obtained, and in the livers of two of them numerous cysts of an undetermined species of Cestode. In the intestines of two also were found a few small Nematodes about 5 mm. long belonging to the genus *Cucullanus*, while in the intestines of two fish two Acanthocephala (Vial No. 15) of the genus *Echinorhynchus* were taken. No Trematodes were present.

Ameiurus nebulosus (Le Sueur): Common Bullhead. Six fish (Nos. 1205b, 1213, 1217) were examined, all of which were infected with parasitic worms, two of them heavily. Two of the fish contained Nematodes, three contained Acanthocephala, four contained Cestodes and three contained Trematodes.

Six specimens of a single species of Nematode were taken from two bullheads. They were small slender worms about 5 mm. in length which belong to the genus *Spinitectus*. Worms belonging to this genus have also been taken from the perch, the carp and the common sunfish in Oneida Lake. But one species has been described as yet in America.

The Cestodes from the bullhead belong to two species. From the middle of the intestines of one fish many small worms belonging to the genus *Corallobothrium* were obtained, being probably the same species as that taken from the yellow bullhead. But one record

* Determination doubtful.

has heretofore been made in this country of this genus, and that was in Wisconsin where it also occurred in the common bullhead. In the liver of three fish were found numerous encysted plerocercoids belonging to some species of tapeworm of the genus *Proteocephalus.*

Two species of minute Trematodes were taken in the bullhead. In the stomach of three fish many individuals about half a millimeter in length were found that belong to an undescribed genus allied to *Plagiorchus.* In the intestine of one fish also were obtained many slender Trematodes about one millimeter in length, compressed and mounted, belonging to an undescribed genus allied to *Allocreadium.*

Three of the six bullheads examined contained a few Acanthocephala (Vial 15) belonging to the genus *Echinorhynchus.*

Anguilla rostrata (Le Sueur): Eel. Two eels (Nos. 1216e, 1251) were examined, and also the viscera from about forty others which were obtained from a fish dealer in Brewerton. They were found to be extensively infected with parasitic worms — Cestodes, Trematodes, Nematodes and Acanthocephala being all represented. Half of the viscera contained Cestodes belonging to two different species. The most numerous species was a tapeworm belonging to the genus *Proteocephalus,* and probably to the species *P. macrocephalus* (Creplin), the length of which was about 200 mm. In most cases but one or two worms were taken from a single intestine, but in two cases the intestine contained a large number of the worms. The other Cestode was also a species of the genus *Proteocephalus,* but much smaller than the one just mentioned. It is a slender worm, measuring from 10 to 15 mm. in length, ten individuals of which were taken from the intestine of a single eel. This genus of tapeworm contains many species common in fresh-water fishes.

Two species of Trematode were taken. In the stomachs of about three-fourths of the fish examined from one to three large distomes belonging to the genus *Azygia* were found. One fish harbored fourteen in its stomach. The worms measured from 18 to 25 mm. in length, compressed and preserved. Species of this genus are common in fresh-water fish and have been taken also in the chain pickerel and the wall-eyed pike in Oneida Lake. Another species of Trematode, belonging to the genus *Crepidastomum,* was found in the intestine of a single eel, nine individuals being taken. The length of the worms was 2 mm., preserved.

But few Nematodes were taken, and these were all of one species. This was a slender worm about 10 mm. in length belonging to the genus *Ascaris,* which was found in small numbers in the intestines of a few eels. The male of this species has two pairs of postanal papillae.

The Acanthocephala were better represented. A single species belonging to the genus *Acanthocephalus* and measuring from 5 to 10 mm. in length was obtained in several intestines.

Cyprinus carpio (Linn.): Carp. Three fish (Nos. 1205c, 1216g) were examined, but one of which was found to be infected with internal parasites. In this fish four Nematodes belonging to the genus *Spinitectus* were taken. Cestodes, Trematodes and Acanthocephala were not found.

Esox reticulatus (Le Sueur): Chain Pickerel. Four fish (No. 1233b) were examined and but few parasitic worms were found. One fish was entirely free from them. In two fish many small Cestodes belonging to the family Proteocephalidae were found in the intestine and in one fish in the rectum, the worms being present in small numbers and all belonging to the same species.

In the stomach of each of two fish was found a single Trematode, both belonging to the genus *Azygia* but to two different species. One of these is a long slender worm with parallel sides and 20 mm. long by 1.25 mm. wide, compressed and preserved; the other is more or less lenticular in shape and 4 mm. long by 8 mm. wide, also compressed and preserved.

In the intestine of one fish a small number of two species of small Acanthocephala (Vial 99) were found. One of these species belongs to the genus *Neoechinorhynchus* and is about 5 mm. in length; the other species belongs to the genus *Acanthocephalus* and has a length of about 6 mm.

No Nematodes were taken in the chain pickerel.

Eupomotis gibbosus (Linn.): Common Sunfish. Five sunfish (Nos. 1233d, 1247c) were examined. One of these fish was infected with cysts of the Trematode *Clinostomum marginatum* (Rudolphi), which was also found in the perch in Oneida Lake, two cysts occuring on the gills and seven at the base of the tail. In the stomach of one fish were found several slender Nematodes about 12 mm. in length belonging to the genus *Spinitectus*. Worms belonging to this genus were also found in the common bullhead, the carp and the perch in Oneida Lake. In the livers of three sunfish were found a small number of large cysts containing immature Cestodes of undetermined affinities. No Acanthocephala were taken.

Lepomis incisor (Cuv. and Val.): Bluegill. Two fish (No. 1205) were examined and the only parasites taken were encysted Trematodes belonging to the genus *Hemistomum,* which were found in the livers of their hosts. When taken from their cysts and extended the worms measured about 1.5 mm. in length. The livers of the fish were quite filled with them. The bluegill is the intermediate host of these worms, the adult host being some species of gull or other fish-eating bird.

Micropterus salmoides (Lacépède): Large-mouthed Black Bass. One fish (No. 1247G) was examined and only Acanthocephala and Trematodes were discovered. Belonging to the first group were a small number of worms of the genus *Neoechinorhynchus* (Vial 120), about 5 mm. in length, which were taken in the intestine. Belonging to the second were a large number of minute distomes of the species *Caecincola parvulus* (Marshall and Gilbert), which were found in the pyloric caeca and the duodenum and which measured about half a millimeter in length. This distome has also been obtained in the same fish in Wisconsin.

Micropterus dolomieu (Lacépède): Small-mouthed Black Bass. Four fish (Nos. 1227a, 1228, 1233h, 1268a) were examined which were found to be rather heavily infected with Trematodes, Cestodes and Acanthocephala. No Nematodes were found.

One species of Trematode was taken. The duodenum and pyloric caeca of all the fish were thickly infected with a minute distome belonging to the species *Crepidastomum cornutum* (Osborn), the length of which, compressed and mounted, averaged one millimeter. This worm was also found in the rock bass in Oneida Lake.

One species of Cestode was found. The liver and the fatty tissue surrounding the pyloric caeca of all the bass examined contained a large number of large cysts of a proteocephaloid tapeworm. The worm taken from its cyst and extended measured about 8 mm.

Two species of Acanthocephala were taken from the intestines of three of the bass examined. One of these belongs to the genus *Neoechinorhynchus* (Vials 72, 75, 182, 183), from one to a dozen worms being found in each fish. Associated with these were also a few worms belonging to the genus *Echinorhynchus* (Vials 73, 75, 77, 182, 183).

Erimyzon sucetta oblongus (Mitchill): Chub Sucker. One fish was examined (No. 1263) and the only internal parasites found were a single Acanthocephalan belonging to the genus *Echinorhynchus* and a single Cestode belonging to an undetermined genus.

Perca flavescens (Mitchill): Perch. Eight fish were examined and were not found to be badly infested with parasites. Five of them contained Trematodes and four contained Nematodes. No Cestodes or Acanthocephala were taken.

Two species of Trematodes were found. One of these is *Clinostomum marginatum* (Rudophi), which was taken from two perch (No. 1225), encysted just beneath the skin on the pectoral fins and at the base of the tail. These worms were immature individuals, the fish being their intermediate host. The adult worms live in the oesophagus and pharynx of herons and other fish-eating birds which become infected with the parasites by eating the fish. The presence of the conspicuous cysts or "grubs," as they are called by fishermen, usually renders the fish unsalable in the markets and grubby fish are thrown away by amateur fishermen, notwithstanding the fact that they are entirely harmless and could not injure anyone eating them with the flesh of the fish. *Clinostomum* is thus of economic significance, especially throughout the summer and early fall when it is most numerous.

The second species of Trematode was found in the stomach of three of the perch examined, but one or two being found in each fish. It is a worm about 8 mm. long when compressed and mounted, which belongs to an undescribed genus allied to *Azygia.*

Of the Nematodes taken in the perch one fish (No. 1249) contained in its stomach several worms of the same species of *Spinitectus* found in the bullhead. Three fish contained each a few individuals in its intestine of a species belonging to the genus *Dacnitoides.* The worms averaged 5 mm. in length.

Pomoxis sparoides (Lacépède): Calico Bass. Two fish were examined, in the intestine of one of which (No. 1220) was found a single Acanthocephalan (Vial 32) belonging to the genus *Pomphorhynchus* and probably of the same species as those found in the golden shiner. No other parasites were taken.

Stizostedion vitreum (Mitchill): Wall-eyed Pike. Nine fish were examined, in one of which no parasites were found. Of the other eight, seven contained Acanthocephala (Vials 5, 84), seven contained Cestodes, and one contained a single Trematode. No Nematodes were taken.

The Trematode was a distome which was obtained from the stomach of its host. It measures, compressed and preserved, 10 mm. long and 1.5 mm. wide and belongs to the genus *Azygia.* Worms of this genus have been described from the stomach of many freshwater fish in America and Europe but have not been found heretofore in the wall-eyed pike.

Three species of Cestodes were taken from the pike. In five of the fish numerous small worms belonging to the genus *Bothriocephalus* were found, the largest of which was 25 mm. long. The location of these worms was the duodenum and pyloric caeca, from the mouth of which they were sometimes found projecting. In the intestines of two fish a few immature worms belonging to the family Proteocephalidae were found, and in two others a few immature Cestodes of unknown affinities.

One species of Acanthocephala was found. The intestine of seven of the pike (Nos. 1233a, 1247e, 1252) contained many worms belonging to the genus *Neoechinorhynchus,* in one fish the worms occurring the entire length of the intestine. This primitive genus has also been found in the chain pickerel, the large-mouth black bass, the small-mouth black bass, and the eel in Oneida Lake, and it is a matter of interest that it is so common in these collections.

Parasites of Birds, Reptiles and Frogs. *Ardea herodias* (Linn.): Great Blue Heron. Four birds were examined and two species of Trematodes and two of Cestodes were found. No Nematodes or Acanthocephala were taken.

In the mouth and upper portion of the oesophagus of all the birds Trematodes belonging to the species *Clinostomum marginatum* (Rudolphi) were obtained, the number of worms in each bird varying from thirteen to twenty-four. The length of the worms ranged from 4 to 10 mm. This Trematode also occurs in cysts under the skin of the perch and sunfish, as already set forth in this report, these fish acting as the intermediate host of the worm. The heron is its final host and harbors the mature, egg-laying worms, which it acquires by feeding on the fish. The eggs of the parasite, falling into the water with the excrement of the bird, give rise to the young worms, which make their way by some unknown means into the fish, and their life-cycle is thus completed.

The second species of Trematode taken was a minute holostome belonging to the genus *Strigea*. Numerous specimens of this worm, which measured about one millimeter in length, were found in the intestine of one of the birds examined. Another species of this genus was also taken in the herring gull on Oneida Lake.

Of the two species of Cestodes taken in the heron one was a very small worm, measuring 10 to 15 mm. in length, which was found in large numbers in the duodenum of one of the birds. It belongs to the genus *Hymenolepis,* a genus which contains many species of small tapeworms parasitic in water birds. The other species was represented by a single specimen, 120 mm. in length, taken from the intestine, and belonging to the family Tetrabothridae.

Ardea virescens (Linn.) : Green Heron. Two birds were examined. *Clinostomum* and *Strigea,* both of which were found in large numbers in the great blue heron, were not found. One Cestode belonging to the same species in the family Tetrabothridae as that taken in the great blue heron was obtained in the intestine. Several Nematodes belonging to the genus *Ascaris* were taken in the intestine of one of the birds. No Trematodes or Acanthocephala were found.

Ceryle alcyon (Linn.) : Kingfisher. Two birds were examined and no internal parasites were taken in either.

Larus argentatus Brünnich: Herring Gull. Two young birds were examined and the rectum and cloacal bursa of one of them was found to be infected with a holostomid Trematode of the genus *Strigea*. The length of the worms varied from 2 to 8 mm. and about twenty were present. Another species of the same genus was also taken from the intestine of the great blue heron. The larvae of these worms are known as tetracotyle forms and have been found in the liver of *Lymnaea catascopium* Say and *L. emarginata* Say in Oneida Lake. It is not likely that the gulls are infected with these parasites by eating the snails but rather that some small snail-eating fish upon which the gulls feed acts as the intermediate host of the worm. No Cestodes, Nematodes or Acanthocephala were found in the herring gulls examined.

Chrysemys marginata (Agassiz): Painted Turtle. Four large turtles were examined, in only one of which parasitic worms were found. The stomach of one turtle contained a tangled mass of Nematode worms averaging 25 mm. in length, belonging to the genus

Strongylus. Worms of this genus have not been found in any other animals in this collection.

Natrix sipedon (Linn.): Water Snake. Nine large snakes were examined and seven were found to be badly infested with parasitic worms. Two snakes contained no parasites.

Six of the snakes contained large Nematodes in their stomachs belonging to the genus *Ascaris,* the length of which was from 50 to 150 mm. In five of these snakes from two to thirty worms were present in each one and the sixth snake contained an extraordinary number of them, its stomach being packed full. Some of the worms had pierced the stomach wall, the head and tail of the worm projecting into the stomach while its middle portion was imbedded in the tissue of the wall.

From the stomach of one of the snakes which contained none of the Nematodes just mentioned were obtained five Acanthocephala, (Vial No. 136) belonging to the genus *Pomphorhynchus.* The length of the worms was about 5 mm. Worms of this genus were also taken in the golden shiner and the calico bass in Oneida Lake.

Two species of Trematodes were obtained. One of these species was taken in the anterior portion of the oesophagus of two of the snakes, four being taken from one and eight from the other. They are elongate worms, measuring about 12 mm. long and 1.5 mm. broad, when compressed and preserved, and belong to an undescribed genus of the subfamily Reniferinae. One of these same snakes also harbored in its stomach a single distome, 5 mm. long and .75 mm. wide when preserved, belonging to an undescribed genus of the family Azygidae.

Two species of Cestodes were found in three snakes: in two snakes they occurred in the intestine and in another snake in the rectum.

Rana pipiens (Scherber): Leopard Frog. Twelve frogs were examined, in one of which, a half-grown animal, no internal parasites were found. All of the others but one contained Trematodes in the lungs, belonging to the genera *Pneumonoeces* and *Tneumobities,* the number of worms in the lungs of any one frog varying from one to nineteen, the average being eight. Six frogs contained Trematodes in the urinary bladder belonging to the genus *Gorgoderina,* the number in a single frog being one or two, with the exception of one frog in which eight were found.

Seven frogs contained Nematodes. In one frog the worms were in the body cavity; in four frogs they were in the lungs; in one frog in the intestine and in one frog in the rectum. These worms were of three different species, all belonging to the family Ascaridae.

No Cestodes or Acanthocephala were taken in the frogs examined.

Parasites of Mollusks. Six species of Pelecypoda, including 14 individuals were examined, and no internal parasites were found in any of them. In *Lampsilis luteola* (Lamarck) from one to four Hydrachnids, belonging to the species *Unionicola aculeata* (Koenike) were found between the gills of each individual examined.

Nineteen species of Gastropoda, including 221 individuals, were examined and of these the following species yielded no internal parasites: *Amnicola limosa* (Say), 20 individuals examined; *Ancylus parallelus* Haldeman, 1 individual examined; *Bythinia tentaculata* (Linn.), 17 individuals examined; *Lymnaea columella* Say, 1 individual examined; *Lymnaea haldermani* Binney, 10 individuals examined; *Planorbis hirsutus* Gould, 10 individuals examined; *Planorbis parvus* Say, 3 individuals examined; *Valvata tricarinata* Say, 35 individuals examined; *Vivipera contectoides* Binney, 3 individuals examined.

The following Gastropoda contained parasites:

Campomela integrum (Say). Three snails were examined, of which the livers of two were infected with a tailless Trematode larva belonging to the genus *Agamodistomum*. The worm is fusiform in shape and about 1.25 mm. long by 5 mm. wide. The worms were not numerous.

Goniobasis livescens (Menke). Twenty-three snails were examined, the livers of six of which were infested with a small number of sporocysts and cystocercous cercariae of large size and similar to *Cercaria anchoroides* Ward. The sporocysts are rather regularly fusiform in shape and from one to two millimeters in length, and contained three or four cercariae each. The free cercariae are about 3 mm. in length, of which the body measures 1 mm. The tail is flat with the anterior half covered with large papillae, and terminates in a pair of flat blades, each .5 mm. in length, which project at right angles. Similar cercariae have been taken previously in four localities in the eastern and central part of this country, in three of which places it was found free-swimming, moving about actively with the tail in advance. It was not found free-swimming in Oneida Lake and when taken from the livers of the snails appeared very sluggish and without definite swimming motions.

Lymnaea catascopium Say. Ten snails were examined, the livers of six of which were infested with two species of larval Trematodes. One of these species is a xiphidiocercaria about .2 mm. long, with a slender tail considerably shorter than the body. The other species is a holostomid belonging to the larval genus *Tetracotyle* and similar to that taken from *Lymnaea emarginata*.

Lymnaea emarginata Say. Five snails were examined, the livers of three of which were heavily infected with holostomids of the larval genus *Tetracotyle*, similar to those found in *Lymnaea catascopium*. These larvae belong to some species of the genus *Strigea* which parasitize fish-eating water birds. Adult worms of this genus have been taken in the herring gull and the great blue heron on Oneida Lake. These interesting larvae are pear-shaped and measure .26 mm. by .19 mm., the oral sucker and sucker-like depressions being at the larger end. Two growth sizes were observed, the smaller being the one just described. The larger one has a large circular forward portion and a tail-like hinder part and measures .49 mm. in length and .41 mm. in width, in the widest place.

Lymnaea palustris (O. F. Müller). Ten snails were examined, of which the livers of six were infested with minute gymnocephalous cercariae. The snails which were not infested were all of small size. In all of these snails one or two oligochaetous Annelids belonging to the genus *Chaetogaster* were found in the mantle cavity.

Lymnaea stagnalis lilliana Baker. Eighteen snails were examined, of which ten contained each one or two Annelids of the genus *Chaetogaster*. No other worms were found.

Physa warreniana Lea. Thirteen snails were examined, the livers of five of which contained numerous rediae and gymnocephalous cercariae. The rediae have a length of 1 mm. The cercariae are about .5 mm. long and have a long slender tail which is about twice the length of the body. Six of the snails had each one or two Annelids of the genus *Chaetogaster* in the mantle cavity.

Planorbis antrosus Conrad. Thirteen snails were examined, the livers of two of which were heavily infected with sporocysts and xiphidiocercariae. One snail had a *Chaetogaster* in the mantle cavity.

Planorbis companulatus Say. Twenty-five snails were examined, of which the livers of six contained numerous sporocysts of undetermined affinities. One or two *Chaetogasters* were taken from each of three snails.

Planorbis trivolvis Say. Nine snails were examined and no internal parasites found. Three snails contained *Chaetogasters* in the mantle cavity.

ACANTHOCEPHALA FROM THE FISHES OF ONEIDA LAKE, NEW YORK*

By Dr. Harley J. Van Cleave

Department of Zoology, University of Illinois

CONTENTS

INTRODUCTION

Through the courtesy of Dr. Charles C. Adams, the writer has been granted the opportunity of examining a collection of Acanthocephala from Oneida Lake, New York. The specimens were collected by Mr. Frank C. Baker and Dr. Henry S. Pratt, between August 23 and September 15, 1917, in the course of investigations of the parasitic worms of Oneida Lake conducted under the direction of The New York State College of Forestry, with the cooperation of the United States Bureau of Fisheries. While only three species of Acanthocephala were encountered during the investigation, the meagerness of biological data concerning these forms makes it appear desirable to present the results in this paper.

The acanthocephalan fauna has been intensively studied for but few localities in North America. Linton made noteworthy contributions ('89, '91, '01, '05) to the knowledge concerning the marine hosts in the vicinity of Woods Hole, Mass., and of Beaufort, N. C. In addition he published the first results ('93) of the intensive study of these parasites from a fresh-water habitat for this continent in his work on the "Fish Entozoa from Yellowstone National Park." More recently the present writer has published the results of extensive investigations upon the occurrence of Acanthocephala in hosts from the Illinois River (Van Cleave, '19) and from Douglas Lake, Michigan ('19a). Most of the remaining records of Acanthocephala on this continent are incidental to studies in taxonomy and morphology, and therefore give only fragmentary bits of evidence of the biological aspects and the distribution of the various species.

Because of the intricacy of the relationship existing between

* Contribution from the Roosevelt Wild Life Forest Experiment Station; and the Zoological Laboratory of the University of Illinois, No. 214.

parasites and their hosts, it becomes a matter of considerable interest to compare the lists of species of parasites found in similar habitats. Only after this has been done carefully for a considerable number of regions will it be possible to offer any very reliable data concerning the distribution of individual species.

HABITS OF ACANTHOCEPHALA

The Acanthocephala constitute a group of parasitic worms the individuals of which have become so thoroughly adapted to the parasitic life that they spend their entire existence within the bodies of other animals. They render no known service to the organisms which they parasitize, but on the contrary inflict damage by appropriating food materials from the host for their growth and development, and by doing violence to the tissues of the host through the action of the spine-covered proboscis or hold-fast organ. Beyond the simple observation that animals heavily infested with these parasites are usually much thinner than those free from infestation, nothing has been done to determine the actual effect of Acanthocephala upon their hosts. As has been pointed out in an earlier paper (Van Cleave, '19, p. 227), it is probable that because of lacerations and punctures of the wall of the intestine, due to the action of the proboscis, these parasites facilitate the entrance of disease-producing organisms into the body of a host.

THE LIFE CYCLE

Relatively little is known concerning the development of North American species of Acanthocephala, but they belong for the most part to the genera that include other species for which the life cycle has been determined wholly or in part. In every species that has been studied two or more hosts have been found essential for the completion of the life cycle. Of these the animal that shelters the sexually mature parasite is called the *definitive host,* while the first organism that harbors the parasite during its larval existence is termed the *primary host.* The definitive host of an acanthocephalan is invariably a vertebrate, while the primary host is usually a crustacean, though insects and insect larvae frequently serve some species in that capacity. Intermediate hosts, though apparently not essential to the development of these worms, are interposed between the primary and definitive hosts in some species. So far as known the acanthocephalans enter the final or definitive host only through the introduction of organisms sheltering the larval worms into the digestive tract of the definitive host. Since these parasites are thus acquired in feeding, their study becomes a matter of considerable importance if we are to understand the full significance of the relationship between hosts of economic importance and their food supply.

The significance of intermediate hosts in the life cycle of the Acanthocephala is apparently not great, for, at least in some instances, they do not seem to be essential links in the chain of development.

Even in species for which intermediate hosts have been discovered it seems fairly clearly demonstrated that infestation of the definitive host may occur directly through the primary host. Adaptation to an intermediate host seems in these forms to be more strictly a facultative adaption to prevent extermination of the individual parasite. If a primary host carried very young larvae these insufficiently developed worms would not be able to establish themselves as intestinal parasites even if the primary host were eaten by a vertebrate which is suitable as a definitive host. Such insufficiently developed larvae, freed in the digestive tract of the vertebrate, must either pass out of the body because of their inability to maintain their position or must penetrate the wall of the digestive tract of the new host. The early appearance of the proboscis hooks would make this latter possibility entirely plausible. Once outside the lumen of the digestive tract the larvae find conditions where they might become encysted and continue the larval development temporarily interrupted by the destruction of the sheltering primary host. It accordingly happens occasionally that a fish serves in the capacities of both definitive and intermediate hosts to the same species of acanthocephalan.

In some instances invertebrates have been reported as intermediate hosts of some species of Acanthocephala. If a primary host bearing larval Acanthocephala were eaten by an invertebrate, the larvae of any stage which escaped destruction might be able to continue their interrupted course of development in their new environment, having acquired thereby a new, though non-essential, link in their developmental cycle.

FACTORS IN DISTRIBUTION

Numerous factors influence the geographical distribution of parasitic organisms having an alternation of hosts. I have previously called attention ('19, p. 229) to the absurdity of assuming that the distribution of such parasites is coextensive with the range of their hosts. Individuals of a given host species may be heavily infested with a given parasite in one part of their range, and entirely free from the same species in other localities. Correlated with this is the fact that a given endoparasitic species may be the dominant parasite of entirely different host species in different regions within its range. Factors controlling these changes are but little understood. Dissimilarity in the food habits of the hosts in various parts of their range might result in the hosts of one locality being heavily infested with parasites while those of another locality would be relatively, if not entirely, free from the same parasites.

It is known that the distribution of some parasitic worms is broader than that of any single species that serves it as host during its larval period. Thus it is possible that in part of its range a species of endoparasite and one of its normal final hosts might occur side by side in the same locality without having their usual intimate interrelationship. Such a condition would be possible if the parasite

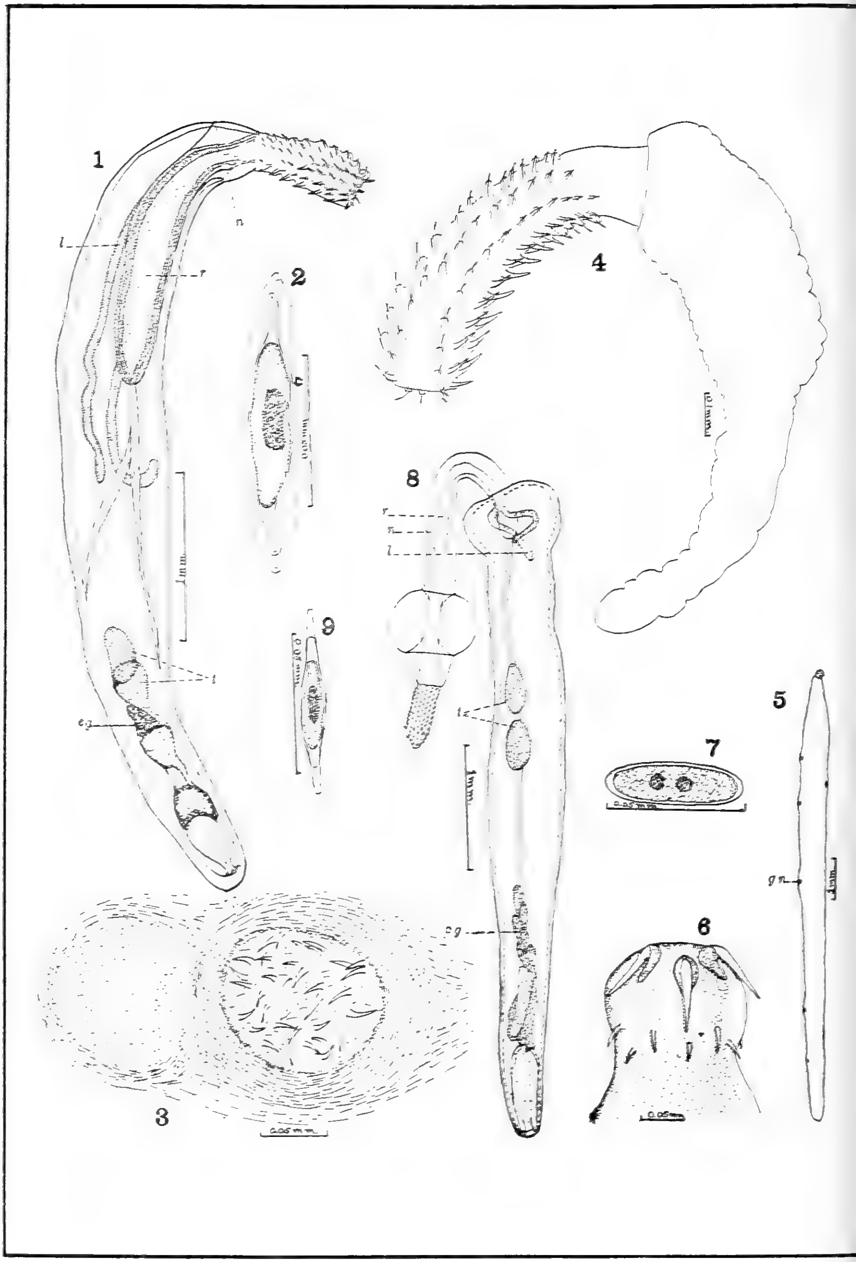

PLATE 2. ONEIDA LAKE ACANTHOCEPHALA.

EXPLANATION OF PLATE 2

All figures were drawn from stained permanent mounts in damar, by the aid of a camera lucida.

Symbols: *c g*, cement gland; *g n*, giant nucleus of subcuticula; *l*, lemniscus; *n*, neck; *r*, receptacle of proboscis; *t*, testis.

Echinorhynchus thecatus (Linton)

Fig. 1. A young male, showing general arrangement of internal organs.

Fig. 2. Hard-shelled embryo from body cavity of a gravid female. Three protective membranes of varying thickness surround the group of cells that have been derived from the fertilized egg cell by cleavage. Embryos are discharged into the water at this stage.

Fig. 3. Larval cyst from peritoneum of yellow perch (from Wisconsin). Fishes may serve this parasite as intermediate hosts. If the amphipod which swallows the hard shelled embryo is unmolested the larva attains its full larval development in the primary host. In case a fish devours a primary host containing slightly developed larvae it seems probable that the larvae become encysted in the tissues of the fish, which thereby becomes an intermediate host, sheltering the larvae until they reach the infecting stage.

Fig. 4. Juvenile form from intestine of fish. This individual is in the same stage of development and is of the same size as the encysted larvae from primary or intermediate hosts.

Neoechinorhynchus cylindratus (Van Cleave)

Fig. 5. Outline drawing showing general body form and the distinctive swellings that indicate the location of the giant nuclei of the body wall.

Fig. 6. Proboscis, showing typical spheroidal form and the number and arrangement of hooks.

Fig. 7. Embryo from body cavity of gravid female.

Pomphorhynchus bulbocolli Linkins

Fig. 8. Young male, showing general arrangement of organs. This species is readily distinguishable by means of the very long neck, which bears an inflated enlargement just behind its attachment to the proboscis.

Fig. 9. Embryo from body cavity of gravid female.

has acquired entirely new hosts through its larvae becoming established in unusual primary hosts that do not enter into the food supply of the host of the mature worm. If the parasite were carried by the migration of its usual normal definitive host into a locality where the larvae failed to find their accustomed primary hosts, the larvae might become adapted to entirely new species of animals in that capacity. If these new species of primary hosts do not enter into the food supply of the unusual definitive host the latter would thereby become freed of the parasite in the newly invaded territory, and the parasite might at the same time acquire as definitive hosts other species which feed upon the newly gained primary host.

DISCUSSION OF SPECIES

But three species of Acanthocephala were encountered in the collections from Oneida Lake, yet in the case of each of these distinctly new biological data have been added. New host species are added to those previously recorded for each of the three species: *Echinorhynchus thecatus* Linton, *Neoechinorhynchus cylindratus* (Van C.), and *Pomphorhynchus bulbocolli* Linkins (in Van Cleave, '19). For the last mentioned species an unusual host, due probably to an accidental infestation, is also recorded.

Echinorhynchus thecatus Linton, 1891.

Length: females 11 to 26 mm.; males 7 to 12 mm. Proboscis usually about 1 mm. long. Neck about one-fourth the length of the proboscis. Proboscis receptacle long and slender, about 1.5 times the length of proboscis. Central nervous system near center of receptacle. Proboscis hooks arranged in 12 longitudinal rows of 12 or 13 hooks each, adjacent rows alternating. Each hook ensheathed in a cuticular collar. Embryos within body cavity of gravid female 80 to 110μ long by 24 to 30μ wide.

This species was by far the most abundantly represented of the acanthocephalans in the fishes of Oneida Lake, having been taken from the digestive tract of six of the nine species which were found parasitized with these worms; for three of these hosts there is no previously published record of the occurrance of this parasite. These new hosts for *E. thecatus* are: the eel (*Anguilla rostrata*), pike perch (*Stizostedion vitreum*), and the chain pickerel (*Esox reticulatus*). The obvious lack of specificity of hosts of this species renders it capable of existence in numerous species of fresh-water and migratory fishes. Many of the records of its occurrence are doubtless due to accidental introduction into unusual hosts where it maintains itself for a time without being able to reach sexual maturity.

In the report on the Acanthocephala from fishes of Douglas Lake, Michigan, I called attention ('19a, p. 6) to the fact that the small-mouthed black bass (*Micropterus dolomieu*) is preeminently the definitive host of *E. thecatus* in that region. The same intimate relationship between this particular host and its parasite is just as clearly demonstrated in the records from Oneida Lake. Most of the fishes of this species examined were infested with *E. thecatus.* Though the infestation was quite general the number of individual parasites removed from the digestive tract of a single host was much smaller than has been observed in other localities. From Oneida Lake fifty-four specimens is the greatest number taken from a single specimen of *M. dolomieu,* while I have frequently taken more than two hundred specimens from a single small-mouthed bass from Lake Pepin, Minnesota.

One of the most interesting records of the occurrence of *E. thecatus* is that of its appearance in relatively large numbers in the digestive tract of *Anguilla rostrata.* This is the first record of the occurrence of this species in the American eel.* Conditions for infestation must have been especially favorable, because each of the four specimens of eel that carried an acanthocephalan infestation yielded *E. thecatus* in numbers ranging from nine to forty-nine. The extent of the infestation and the number of parasites from each host is fully as great as that for small-mouthed black bass of the same locality, though the latter has been generally recognized as the normal host of *E. thecatus.* For this reason it does not seem probable that the infestation of *Anguilla rostrata* in Oneida Lake could be considered as accidental.

The writer has discovered *E. thecatus* in the intestine of the pike-perch from other localities, but this is the first published record of its occurrence in this host.

The number of specimens of each fish examined was in each instance too small to justify any statements regarding percentages of infestation. Since, however, the available data are of interest in showing the relative extent of infestation, the results of the examinations for this and the following species are arranged in tabular form.

Table I.

Analysis of the occurrence of *E. thecatus* in Oneida Lake hosts

HOST SPECIES	Number infested with Acanthocephala	Vial numbers	Number infested with *E. thecatus*	Specimens in individual hosts
Anguilla rostrata	4	36, 54, 56, 125	4	9–49
Micropterus dolomieu	7	73, 75, 77, 182, 183	5	1–54
Ameiurus nebulosus **	3	15	1	2
Stizostedion vitreum	4	84	1	3
Ambloplites rupestris	1	79	1	7
Esox reticulatus	1	99	1	2

*Van Cleave, 1920a, published after this report went to press.
** Determination doubtful, as careful distinction was not always made between *A. natalis* and *A. nebulosus.*

In a recent paper (Van Cleave, '20) the writer has outlined the trend of development of this species. Larvae of *E. thecatus* have been found undergoing their development in the amphipod crustacean *Hyalella knickerbockeri.* Evidence already cited in this paper seems to prove that infestation of the definitive host may occur directly through this primary host. On the other hand, encysted larvae of this species have been taken from the mesenteries of *Perca flavescens, Micropterus salmoides, Ambloplites rupestris,* and *Percina caprodes,* thus demonstrating that these species may serve as intermediate hosts of *E. thecatus.* Since *Hyalella* is included in the fauna of Oneida Lake, it is entirely probable that it serves as primary host of *E. thecatus* though no actual demonstration of this fact is at hand.

Neoechinorhynchus cylindratus (Van Cleave, 1913).

Body large, almost cylindrical, except in young forms, in which the posterior extremity is gradually narrowed. Females 10 to 15 mm. long, with a maximum diameter of 0.7 mm. Males 4.5 to 8.5 mm. long and 0.5 to 0.7 in diameter. Proboscis slightly broader than long (0.172 by 0.150 mm.). Proboscis hooks arranged in three circles of six hooks each. Embryos within gravid female 49 to 51μ long by 15 to 21μ broad.

Neoechinorhynchus cylindratus is the only representative of the family Neoechinorhynchidae encountered in the collections from Oneida Lake. Five of the nine species of fish carrying Acanthocephala harbored this species. As hosts for this species, *Esox reticulatus* and *Stizostedion vitreum* are made a matter of record for the first time. The writer has encountered *N. cylindratus* in the pike-perch from the upper Mississippi River, and from Lake Erie at Sandusky, Ohio, but there is no previously published record of the occurrence in this host.

Table II.

Analysis of the occurrence of *N. cylindratus* in Oneida Lake hosts

HOST SPECIES	Number infested with Acanthocephala	Vial numbers	Number infested with *N. cylindratus*	Specimens in individual hosts
Stizostedion vitreum	4	5, 84	4	1–32
Micropterus dolomieu	7	72, 74, 75, 182, 183	5	1–10
Micropterus salmoides	1	120	1	3
Esox reticulatus	1	99	1	3
Anguilla rostrata	4	125	1	6

From the above table it is obvious that *Stizostedion vitreum* is the most generally utilized host of *N. cylindratus* in Oneida Lake. The six specimens taken from one individual of *A. rostrata* were all immature, though gravid females of this parasite have been taken from the eel at Woods Hole, Mass., (Van Cleave, '13, p. 188), thus indicating that the eel is not an accidental host but serves as a normal definitive host in which *N. cylindratus* may complete its developmental cycle.

The large-mouthed black bass (*Micropterus salmoides*) is the host from which the type material of this species was taken in Pelican Lake, Minn., (Van Cleave, '13, p. 187), yet the single specimen of this species found infested in the Oneida Lake investigations carried an extremly light infestation by this parasite. Thus it becomes evident that a parasite may in different parts of its geographical range infest the same host species in widely varying degrees. Not only is there no necessary correlation between the distribution of a parasite and that of its type host, but even when the range of the two are coextensive the parasite may be the dominant parasitic guest of entirely different hosts in different localities.

Nothing is known regarding the development of *N. cylindratus.* Villot ('84) worked upon the development of a European representative (*N. rutili*) of the same genus, and found that the larval development occurs in the aquatic larvae of *Sialis.* It is entirely probable that some aquatic insect larva shelters the developing young of *N. cylindratus.*

Pomphorhynchus bulbocolli Linkins, 1919.

Body elongate, tapering toward posterior end. Neck prominent, measuring 2.6 to 4 mm. in length; diameter 0.15 to 0.4 mm. in posterior region and 0.8 to 1.5 mm. in region of spherical enlargement. Proboscis cylindrical, 0.5 to 0.6 mm. long by 0.7 to 0.2 mm. in diameter, armed with 24 to 28 circular rows of hooks. Basal circle with 12 hooks, remaining circles with 6 each. Embryos within body cavity of gravid female 53 to 83μ long by 8 to 13μ broad.

In so far as known, fishes are the only normal hosts of the adult parasite belonging to the genus *Pomphorhynchus.* Many hosts throughout the United States have been found to harbor this species though there have been few published records of its occurrence, owing to the fact that many of the early workers recorded the finding of the European species in this country without giving descriptions sufficient to verify or disprove their claims. It seems probable that all of the early records of *Echinorhynchus proteus* (= *P. laevis*) from North America should be referred to the distinctively American species *P. bulbocolli.* Only three species of fishes from Oneida Lake were found to harbor *P. bulbocolli,* but in addition a very unusual instance of its occurrence in the water snake (*Natrix sipedon*) was discovered. One specimen of *N. sipedon* contained five small individuals of this species in the stomach. The presence in this host was, without doubt, accidental, the worms having been taken into the stomach of the snake incidentally with one of their normal hosts which was devoured by the snake for food. It is extremely doubtful if the parasites could have become permanently established in this strange environment. Such unusual occurrences are occasionally met with in general collecting, and are likely to lead to confusion if not correctly interpreted. The accidental appearance of an organism in the digestive tract of a given animal does not necessarily demonstrate that it has become established there as a parasite. The only true criterion for the determination of what constitutes a normal definitive host is the ability of the parasite to perfect its sexual development.

TABLE III.

Analysis of the occurrence of *P. bulbocolli* in Oneida Lake hosts

HOST SPECIES	Number infested with Acanthocephala	Vial nos.	Number infested with *P. bulbocolli*	Specimens in individual hosts
*Ameiurus nebulosus**	3	20, 27	2	2–3
Abramis crysoleucas	1	31	1	11
Pomoxis sparoides	1	32	1	1
Natrix sipedon	1	136	1	5

* Determination doubtful, as careful distinction was not always made between *A. natalis* and *A. nebulosus*.

One species of fish is added to the hosts previously recorded for *P. bulbocolli* in the record of its occurrence in the intestine of the golden shiner (*Abramis crysoleucas*).

Nothing is known regarding the development of *P. bulbocolli*. In 1872 R. Leuckart described the larva of a European representative of this genus from the body of the amphipod *Gammarus pulex*. Since that time several fishes have been reported as intermediate hosts of the European species *P. laevis* (= *E. proteus*).

CONCLUSIONS

But three species of Acanthocephala have been encountered in the fishes of Oneida Lake. All of these are of broad distribution in fresh-water habitats in North America. It is noteworthy that no species distinctive for the locality were discovered. This stands in rather sharp contrast with the conditions encountered in two other fresh-water habitats studied intensively by me, in each of which species of apparently restricted distribution were found. From the fishes of Douglas Lake, Michigan (Van Cleave '19a), two of the four species of Acanthocephala encountered were new, and collections from the surrounding states seem to indicate that each of these is rather sharply limited in its distribution. Similarly, from the fishes of the Illinois River (Van Cleave, '19) two species of Acanthocephala distinctively local in distribution were taken. In spite of the fact that *Gracilisentis gracilisentis* and *Tanaorhamphus longirostris* were locally abundant in *Dorosoma cepedianum* from regions about Peoria and Havana, Illinois, extensive collections from other parts of the continent have never produced them from any other localities.

Pond and lake conditions furnish by far the most favorable environment for development of excessive infestations by Acanthocephala, yet on the whole the infestations of individual hosts from Oneida Lake were relatively light.

In the region under consideration the influence of migratory fishes, such as the eels, in the dispersal of various species of Acanthocephala seems to be negligible. In some localities migratory fishes are reported to have caused a mixing of fresh-water and marine species of Acanthocephala. Many species of Acanthocephala lack definite restrictions as to specific hosts. As a consequence they are facultative parasites of many diverse kinds of fish. Thus the eels from Oneida Lake have been found to harbor the two species of Acanthocephala most abundantly represented in that local fauna. Apparently the fresh-water acanthocephalan fauna has not been enriched by the addition of species recently introduced from the ocean by migratory fishes.

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CURRENT STATION NOTES

THE INTENSIVE USE OF FOREST PARKS

In the last number of the *Bulletin* reference was made to the intensive recreational use of forests by great crowds of people from the large cities, and attention was called to the new problems arising as a result of this new situation. On the shores of Carr Pond, in the Palisades Interstate Park on the Hudson River, numerous permanent camps have been located for children, most of whom come from the crowded sections of New York City. The opportunities for bathing in this Pond are one of the chief attractions of these camps. The various camp leaders and the Park authorities, in 1919, became greatly concerned with complaints about the abundance of large leeches which disturbed the bathers. This problem became so serious and was of so much practical importance, that, through Mr. Edward F. Brown, at that time Superintendent of the Camp Department of the Park, the Commissioners sought the cooperation and assistance of the Roosevelt Wild Life Station to find a means of abating this nuisance. Dr. J. Percy Moore, of the University of Pennsylvania at Philadelphia, our leading authority on leeches in America, was called upon to assist in this matter. As he was already working on the problem of mosquito control by means of fishes, for the United States Bureau of Fisheries, a general cooperative plan was made between these three agencies, the Commissioners, the Bureau and the Station. Dr. Moore thus began his study of devising methods of controlling leeches, and secondarily, extended his studies of mosquito control. His report in this number of the *Bulletin,* is the first published investigation of this character.

At first sight it might seem that a study of leeches would have but little practical significance, until it is recalled that control of the leeches was originally a practical administrative difficulty, demanding attention, and that this led to the investigation. We are thus reminded how intensive use of these great forest parks is destined to present problems wholly new and calling for technical study. Looking to the future we anticipate many similar problems awaiting attention in large forest parks now being developed for recreational purposes.

THE SICKNESS OF WILD ANIMALS

All are familiar with the fact that when domestic animals become sick it is possible to call upon professionally trained men to assist in their care. But whose concern is it to look after wild animals when they are sick? We have not yet evolved a profession occupied solely with this responsibility. The Roosevelt Station, recognizing this need, is making an effort to supply in part the deficiency. As wild life belongs to the State and Nation, and therefore to the public, there has been very little of the personal concern for its welfare that accompanies private ownership. In looking forward towards constructive measures for the proper maintenance of the wild life of our forests, the time is fast approaching when adequate provision should be made for a study of its diseases.

Fishermen and anglers frequently meet with diseased fish, but at present we know so little about the habits and life histories of disease-producing organisms that we are generally unable to protect our food and game fish. With a view towards making an inventory of the worm-caused diseases of Oneida Lake fish a cooperative survey was arranged between the United States Bureau of Fisheries and the College of Forestry, and Dr. Henry S. Pratt of Haverford College, Pennsylvania, and Mr. Frank C. Baker, then of the College, made a study of the parasitic worms of this lake. The paper by Dr. H. J. Van Cleave is based upon specimens collected by Messrs. Pratt and Baker. Other reports extending these investigations are in preparation.

THE ROOSEVELT WILD LIFE MEMORIAL

As a State Memorial

The State of New York is the trustee of this wild life Memorial to Theodore Roosevelt. The New York State College of Forestry at Syracuse is a State institution supported solely by State funds, and the Roosevelt Wild Life Forest Experiment Station is a part of this institution. The Trustees are State officials. A legislative mandate instructed them as follows:

"To establish and conduct an experimental station to be known as 'Roosevelt Wild Life Forest Experiment Station,' in which there shall be maintained records of the results of the experiments and investigations made and research work accomplished; also a library of works, publications, papers and data having to do with wild life, together with means for practical illustration and demonstration, which library shall, at all reasonable hours, be open to the public." [Laws of New York, chapter 536. Became a law May 10, 1919.]

As a General Memorial

While this Memorial Station was founded by New York State, its functions are not limited solely to the State. The Trustees are further authorized to cooperate with other agencies, so that the work is by no means limited to the boundaries of the State or by State funds. Provision for this has been made by the law as follows:

"To enter into any contract necessary or appropriate for carrying out any of the purposes or objects of the College, including such as shall involve cooperation with any person, corporation or association or any department of the government of the State of New York or of the United States in laboratory, experimental, investigative or research work, and the acceptance from such person, corporation, association, or department of the State or Federal government of gifts or contributions of money, expert service, labor, materials, apparatus, appliances or other property in connection therewith." [Laws of New York, chapter 42. Became a law March 7, 1918.]

By these laws the Empire State has made provision to conduct forest wild life research upon a comprehensive basis, and on a plan as broad as that approved by Theodore Roosevelt himself.

Form of Bequest to the Roosevelt Wild Life Memorial

I hereby give and bequeath to the Roosevelt Wild Life Forest Experiment Station of The New York State College of Forestry at Syracuse, for wild life research, library, and for publication, the sum of ...., or the following books, lands, etc.

Syracuse Univ. Bull. Vol. 23 February, 1924 Number 4

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2. **Roosevelt Wild Life Annals.**

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THE RELATION OF FORESTS AND FORESTRY TO HUMAN WELFARE

"Forests are more than trees. They are rather land areas on which are associated various forms of plant and animal life. The forester must deal with all. Wild life is as essentially and legitimately a part of his care as are water, wood and forage. Forest administration should be planned with a view to realizing all possible benefits from the land areas handled. It should take account of their indirect value for recreation and health as well as their value for the production of salable material; and of their value for the production of meat, hides and furs of all kinds as well as for the production of wood and the protection of water supplies.

"Unquestionably the working out of a program of wild life protection which will give due weight to all the interests affected is a delicate task. It is impossible to harmonize the differences between the economic, the esthetic, the sporting and the commercial viewpoints. Nevertheless, the practical difficulties are not so great as they appear on the surface."

HENRY S. GRAVES,
Former Chief Forester, U. S. Forest Service.
Recreation, Vol. 52, p. 236; 1915.

"Outdoor recreation is a necessity of civilized life, and as civilization becomes more intensive the demand grows keener. The vast extent of our present National Forests, their enticing wildness, and the notable beauty of the native landscape lure men and women thither by hundreds of thousands. The really enormous extent and value of this kind of forest product has been generally overlooked in America. This oversight, however, is only local and temporary. In older countries, where public forests have existed for centuries, the recreation use of such areas has always been recognized. It would be perfectly easy to show that recreation was, in fact, the original and primary purpose in the creation of public forests.

"The moment that recreation (using this word in a very liberal meaning) is recognized as a legitimate Forest utility the way is opened for a more intelligent administration of the National Forests. Recreation then takes its proper place along with all other utilities. In each particular case these utilities are weighed against one another and a plan of administration devised to adjust and harmonize, to the utmost point practicable, the various forms of use so that the largest net total of public good may be secured. Where one must be subordinated to another, preference is given to that of highest value to the public."

FRANK A. WAUGH,
Collaborator, U. S. Forest Service.
Recreation Uses on the National Forests, pp. 3-4, 5; 1918.

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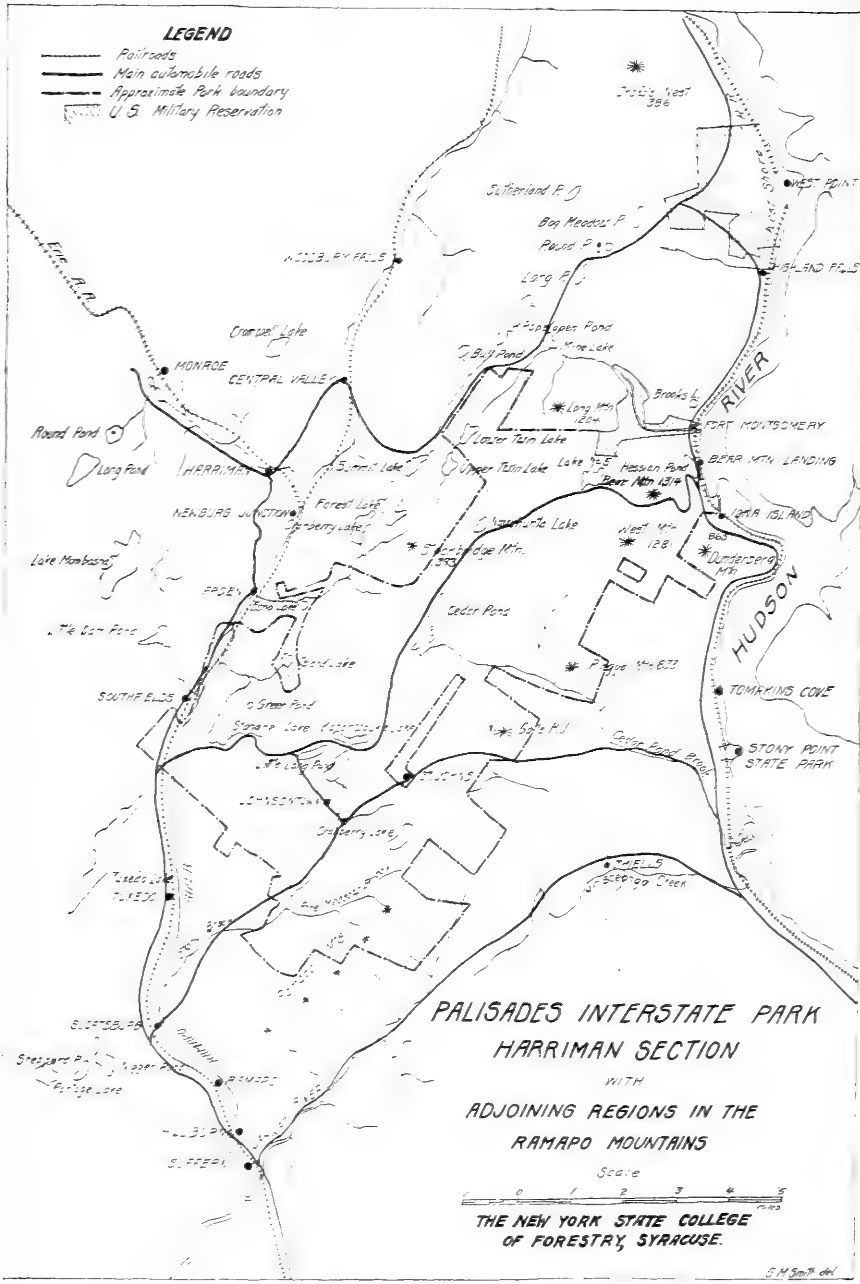

Map. 1. The Harriman Section of the Palisades Interstate Park.

ECOLOGY OF THE PLANKTON ALGAE IN THE PALISADES INTERSTATE PARK, INCLUDING THE RELATION OF CONTROL METHODS TO FISH CULTURE*

By Dr. Gilbert Morgan Smith

Collaborator, Roosevelt Field Naturalist, Roosevelt Wild Life Forest Experiment Station, Syracuse, New York.

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* This investigation of the water blooms, caused by the growth of algae in fresh water, is an excellent illustration of the results of the intensive use of forest regions for recreation. These Park waters are used by thousands of Park visitors. In the efforts of the Park officials to control the bloom by the use of the copper sulphate method it was at once seen that this method infringed upon the methods of fish culture which are being developed. It will probably be a long time before many of the remote forests, both State and National, will meet with urgent practical problems of this character, which result from close proximity to the large cities. Furthermore, this experience with bloom and fish culture shows that such problems must be investigated by technical men before they can be solved administratively. The present investigation was made at the request of the Commissioners of the Palisades Interstate Park, and with their cooperation. It is a pleasure to acknowledge the cordial assistance received from the late Mr. George W. Perkins, President of the Commissioners, and from Mr. Edward F. Brown, at that time Superintendent of the Camp Department of the Park. Assistance was also gratefully received from Mr. W. A. Welch, then Chief Engineer, and now General Manager of the Park.— The Director.

THE PALISADES PARK AND ITS LAKES

The Palisades Interstate Park, under the joint supervision of the States of New York and New Jersey, is not comprehended in a single area but consists of four tracts of land on the west shore of the Hudson River. The largest of these, the Bear Mountain and Harriman tract, comprises more than 25,000 acres of mountain and forest lands in the Highlands of the Hudson just below West Point, New York, and extends back through Rockland and Orange Counties to Tuxedo (Map 1). It is this section that the Commissioners are developing for recreational purposes on a large scale and with which the present report deals. This investigation was made in July and August, 1918.

The general physical conditions of the Park have been described by Silloway ('20), while Brown ('20) has given the administrative ideals of the Park management in developing the Park as a recreational center. The general geological aspects of the region have been discussed by Ries ('95) and Darton ('90).

Within the boundaries of the Park are natural bodies of water, lakes that are wholly artificial, and natural lakes whose volume has been considerably increased by artificial means. Since all of the artificial lakes, and all dams raising the level of the water, have been constructed within the past five years, the survey was extended beyond the Park boundaries in order to include several old artificial lakes that have existed, in certain cases, for over a hundred years. The history of these various bodies of water has been compiled from county histories and old atlases,* but in several instances the information is very fragmentary. Sufficient information was obtained to show, however, that there are several artificial lakes in the neighborhood of the Park that are over fifty years old, and their importance in furnishing a forecast on the future algal succession in artificial lakes within the Park cannot be overestimated. Soundings were also made in lakes within the Park to determine the volume of these bodies of water. In a few instances soundings were made in lakes outside the Park, and in others data were supplied by people familiar with the different bodies of water, but in the use of such data the tendency towards exaggeration is recognized.

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* The following publications have been utilized in determining the history and origin of the different bodies of water:

Anonymous. The Country West of Hudson's or North River Occupied by the American Armies Under Washington. From a Manuscript Map Drawn by Lord Sterling in 1779 [referred to as the Sterling Map].

Burr, D. S. An Atlas of the State of New York. New York. 1829.

Cole, D. History of Rockland County, New York. New York. 1884.

Eager, S. W. An Outline History of Orange County, New York. Newburgh, N. Y. 1846–7.

Hopkins, G. M. Combined Atlas of the State of New Jersey and the County of Hudson. Philadelphia. 1873.

Ruttenber, E. M. and Clark, L. H. History of Orange County, New York. Philadelphia. 1881.

Smock, J. C. First Report on the Iron Mines and Ore Deposits in the State of New York. Bull. N. Y. State Mus. of Nat. Hist., Vol. 7, pp. 1-70. 1889.

Sterling — see Anonymous.

Description of the Lakes. The following list comprises the lakes investigated, with all available data on size, depth, and origin. The names of the lakes within the Park boundaries are the official names recognized by the Park authorities, while the names of lakes outside of the Park are those that appear on the West Point, Stony Point, Ramapo, and Schunemunk quadrangles of the United States Topographical Survey; these names are, in one or two instances, at variance with local usage.

1. *Barnes Lake:* A small, very shallow, artificial lake made by a damming of the stream running from Lower Twin Lake. It is not more than five years old.

2. *Cedar Lake:* In the middle of the Park, and formed by a concrete dam made a few years ago. Previous to the building of the dam there were two small natural lakes, which are shown on the Stony Point sheet of the United States Topographical Survey map as Cedar Pond and Little Cedar Pond. The water of the enlarged Cedar Lake has a maximum depth of 35 feet. It is the source of the municipal water supply for the town of Haverstraw.

3. *Cranberry Lake:* An old artificial lake on the Harriman estate, north of the Park, built to furnish power for the Clove iron mine in 1857 or 1858. Mr. R. D. A. Parrott, a former owner of the property, states that there was no natural pond in the basin at the time that the dam was built. This lake has a length of .64 miles and a breadth of .15 miles. It is comparatively shallow, with a maximum depth of sixteen feet and an average depth of twelve feet.

4. *Cromwell Lake:* Called Hazzard's Pond on all old maps, this lake is located in the western part of Woodbury township and has a length of .50 and a maximum breadth of .25 miles. The total area is approximately 42 acres, the greatest depth 45 feet, and the average depth 20 feet. The lake is a natural one, although a dam built between 1740 and 1745 raised the water three feet. At the time collections were made the water was quite turbid as a result of heavy algal growths. Such growths are by no means uncommon during the summer months.

5. *Echo Lake:* Another old artificial lake, lying on the Harriman estate, was built to furnish power for the Greenwood iron furnace. Mr. Parrott informs me that the furnace was rebuilt in 1813, but he does not know when the furnace was first built. The lake bottom is badly silted up and the lake is very shallow, having a maximum depth of eight and an average depth of six feet. Its length is .28 miles, and its breadth a tenth of a mile.

6. *Forest Lake:* This lake is shown on the Sterling map of 1779 and on several more recent maps. It is called Slaughter's Pond on all of these maps. A dam, which raised the water-level twelve feet was built across the outlet in 1856, and in 1916 another addition to the dam increased the depth of the water three feet. The lake has been carefully sounded by the caretaker who reports a maximum depth of 58 feet. The greatest depth that I have found is 56 feet. The lake is three quarters of a mile long and of irregular shape.

7. *Green Pond:* The smallest natural lake within the boundaries of the Park lies just east of Stahahe Lake. It is a small circular body of water with a diameter of a tenth of a mile and a maximum depth of eight feet. The encroachment of vegetation from the shores and the silting up of the bottom have reached an advanced stage, and the lake will disappear completely in a short time.

8. *Highland or Hessian Lake:* Found in the extreme eastern part of the Park, just a few hundred feet back from the Hudson River and 350 feet above it. It is a natural lake bearing the old Indian name Sinnipink, according to Cole. The length is .52 miles, breadth .15 miles, and depth about 35 feet.

9. *Island Lake:* It lies in the southern part of the Harriman estate and is one of the smallest natural lakes studied. At the same time its depth is nearly three times that of any other lake of the region that was visited. It is a summit lake which originally drained both north and south, but the construction of a dam raised the water-level three or four feet and caused all of the water to flow into Echo lake. It has a length of .35 of a mile and a breadth of a quarter of a mile. The deepest part of the lake is 126 feet and an average of 35 soundings taken in the northern half was 91 feet.

10, 11. *Upper and Lower Kanahwauke Lakes:* These lakes are wholly artificial and were constructed by the Park authorities in 1914 by building two dams across the valley of Stillwater Creek, which rises in Little Long Pond. Both of these lakes are shallow and about a mile long.

12. *Little Dam Lake:* Made by damming the stream flowing from Lake Mombasha in the northern part of Tuxedo Township. Ruttenber and Clark state that the Southfield works were established in 1805 or 1806, and the presumption is that this old mill-pond was built at about that time. At present it is a very shallow body of water with the macrophytic vegetation encroaching from all sides. It is rather irregular in shape with a maximum length of three fourths of a mile and a breadth of an eighth of a mile.

13. *Little Long Pond:* The largest natural lake within the boundaries of the Park lies in the western portion between Cedar and Stahahe Lakes. It is shown on the Sterling map of 1779 as Long Pond. In 1914 the depth of the water was increased about three feet by the construction of a dam at the outlet. The dimensions of the lake are thirty-five by eleven hundredths of a mile; the average depth is 21 feet and the maximum depth 33 feet.

14. *Long Pond:* Another body of water outside of the Park limits is about three miles west of Highland Falls. It is a natural lake shown on all old maps, but I am unable to find whether or not its level has been raised by dams. It is .56 of a mile long and .15 broad.

15. *Mine Lake:* A half mile east of Popolopen Pond, is undoubtedly an artificial pond built to furnish power for the Forest of Dean

mine. Since Smock states that this mine was in operation before 1777 we may infer that the pond is a very old one. It is a shallow body of water with a length of three tenths of a mile and a breadth of about half the length.

16. *Lake Mombasha:* A natural lake in the southern part of Monroe Township that is shown on all old maps as Mount Basha Lake or Pond. It is the largest body of water investigated, being a mile and a half long and a half-mile broad. There is a dam across the outlet but I have been unable to ascertain the time at which it was built or how much it increased the maximum depth of the water, which is now in the neighborhood of fifty feet. This lake furnishes the water supply of the town of Monroe.

17. *Nigger Pond:* Lying in the northwest portion of Ramapo Township, has a breadth of a quarter of a mile and a length three times the breadth. It is artificial, and was formed many years ago by impounding the waters flowing from Portage Pond. In the Beers (1872) and Hopkins (1873) maps this pond is not shown, so that it was probably built at some time subsequent to 1873. The Beers and Hopkins maps both show a Negro Pond, but that is the Portage Lake of the United States topographical maps. About 1902 the dam forming Nigger Pond was rebuilt, and during the time of its reconstruction the water was drained off.

18. *Popolopen Pond:* At the extreme west of Highland Township, is one of the largest lakes of the region. It appears on all maps of the district, including the Sterling map of 1779. Eager (1846) states: "This pond now covers 3,000 acres. It has been dammed up to increase the reservoir of the Ft. Montgomery Mills and the water is from 25-30 feet deep." The pond has a length of one mile and a breadth of one third of a mile.

19. *Portage Lake:* A lake just above Nigger Pond that is shown on the Burr map of 1829 as an unnamed body of water, but which appears on the Beers and Hopkins (1873) maps as Negro Pond. There is a very old dam at the lower end. I have been unable to find from old residents whether or not this lake is entirely artificial or an enlarged natural lake. No soundings were made in this lake, which has a length of three fifths and a breadth of one fifth of a mile.

20. *Queensboro Lake:* Another small artificial lake in the eastern portion of the Park that has been built by the Park authorities.

21. *Rockland Lake:* Although on Park property this lake lies some distance south of the Harriman section. It is a natural lake which was called *Quashpeake* by the Indians until the settlement of the region.

22. *Shepard Pond:* Forming the third of a small group of lakes of which Portage and Nigger are the other two. It is probably a natural lake and is shown on the Burr atlas of 1829. It is a third of a mile long and a quarter of a mile broad. Nothing is known concerning its depth.

23. *Stahahe Lake:* Formed by enlarging a small natural lake in the western part of the Park; also known as Carr Pond. The enlarged lake is about three quarters of a mile long, half as broad, and has a depth of about 25 feet.

24. *Summit Lake:* Lying between Forest and Twin lakes it was formerly a small natural lake which was increased to its present size some forty years ago. Judging by the topography of the bottom, as shown by numerous soundings, the original lake was about half the size of the present one. At present the length is six tenths of a mile, the breadth a sixth of a mile, while the average depth is 20 feet and the maximum depth 27 feet.

25, 26. *Upper and Lower Twin Lakes:* These lakes are found just outside of the Park, and both are natural lakes. Upper Twin Lake has a length of three tenths of a mile and is reported to be 100 feet deep. A dam built at the outlet of the lake in 1841 raised the water level three feet. According to all available information, the depth of the water in Lower Twin Lake has never been increased artificially. The greatest depth found in this lake was 35 feet, and depths of 12 to 15 feet were found seventy-five feet from the shore. The length of this lake is one third of a mile and the breadth one tenth of a mile.

WATER BLOOMS AND THE FACTORS GOVERNING THEIR FORMATION

The Nature of Algal Blooms. Anyone who has been upon lakes in the summer, especially in the month of August, has noticed that at times the water is no longer clear, but turbid, the minute particles causing this turbidity generally being green or yellowish green in color. This change in the condition of the water may take place in a few days and then persist for some weeks, or it may disappear in a few days and the waters resume their original clearness. Although the term "blooming" is generally applied to this phenomenon it is known by various names in different localities, and the terms "working," "fermenting," or "purging" are also applied.

The cause of this change in the condition of the water is a frequent subject of debate to the dweller at the lakeside, but microscopical examination of the water has shown that in every case it is brought about by the presence of large numbers of microscopic organisms, generally minute plants known as algae. The algae form the simplest group of plants and are not composed of leaves, roots and stems, but of single cells — the units of structure which make up the higher plants,—or they may comprise a number of cells that form a chain or other simple structure. The number of fresh-water algae recognized by the botanist is very large and includes the green thread-like scums of ponds and ditches, the moss-like growths in the beds of streams or along lakeshores, as well as the mat-like growths that can be noted at times on the muddy banks or on the shallow bottoms of lakes.

If a funnel-shaped net made of the finest miller's bolting cloth is drawn through the water of a lake for a while, one always finds at the bottom of the net a brownish to greenish sludge which a microscopical examination shows is composed of algae and simple animals. The algae that live free-floating in the middle of the large lakes are, as a rule, quite distinct from those dwelling on the shallow bottom or along the shore, and they form a flora that, for the biologist, differs as much from the shore and bottom algal growths as a tropical flora differs from that of New York. This special free-floating minute life found in mid-lake is known as the plankton, and the algal or plant portion of it is called the phytoplankton. Even the clearest lake, and one which never develops a bloom, has its plankton flora, and though the total number of individuals in a gallon of water may be small there may be surprisingly different types present. In fact, the students of these minute organisms have made some of their richest collections of species in clear-water lakes. It matters not at what season of the year the collections are made, plankton algae will always be present in the lakes; although they are much more common at certain seasons, especially midsummer, than at others. The kinds of algae found also vary from month to month, some being most abundant in early spring, others in midsummer, and still others in greatest quantity in the fall.

Injurious Effects of Blooms. The question is often asked whether an algal bloom is really inimical to the health of man or animals drinking the water. Although there have been reports of mysterious deaths of farm animals that have been ascribed to the drinking of water containing large numbers of algae (Nelson, '03; Francis, '78; and Arthur, '84) there seems to be but little direct evidence that bloom organisms contain poisonous substances. The widespread occurrence of blooms in lakes every year, and the wide use of these lake waters by domestic animals, furnishes justification for the statement that these organisms are not directly poisonous.

Cases have been reported, likewise, where the sudden dying of fish has been considered due to the presence of heavy algal growths. Among these may be mentioned the observations of Haine ('18), Hyams and Richards ('01), and Baldwin and Whipple ('06). Those of Baldwin and Whipple have been the most complete, and their results show that while the algae killed the fish they did not poison them directly, but that the death of the algae following their period of blooming caused an exhaustion of the oxygen supply, and that, in turn, caused the death of the fish. That this death of fish in connection with blooming is due to the exhaustion of oxygen is borne out by the observations of Haine, who shows that when algae have been killed by copper sulphate there is a sharp decrease in the oxygen content of the water following such treatment, due to the bacterial oxidation of the dead algae, and that this oxygen reduction may affect the fish.

Although the direct effects of blooms upon the life in the water or upon the animals using the water for drinking purposes are small, blooms are of great importance from the aesthetic point of view. When a lake contains heavy algal growths the odors arising from the putrefaction of the algae are frequently apparent along the shore, and may interfere seriously with the utilization of the lake as a recreational center. This has been the experience in the Palisades Park, and the blooming in Stahahe Lake during the summer of 1918 marred the camp life both by the odors permeating the region and by its discouragement of bathing.

The growth of algae in water reservoirs is of even greater economic importance, since their presence, even in too small quantities to form a noticeable bloom, may seriously affect the taste of the water. This effect of algal growths upon the taste of water is outside the problem under consideration, although it should be noted that the greatest demand for a study of algal growths and especially of methods for their eradication, has come from the water supply engineers.

Rate of Growth of Algae. Algae are always present in lakes and it is merely a matter of their multiplication until they occur in sufficient abundance to form a mass of suspended particles discernible to the naked eye. The simplicity of the algal structure, which is usually but a single cell, is correlated with the rapidity of multiplication. In the reproduction of algae there is a division of the original parent-cell into two daughter-cells that soon grow to the size of the original one. As soon as these cells have attained the size of the parent-cell, either two plants are present, or, in the case of forms that do not consist of single cells, the number of component cells has been doubled. This life cycle is of short duration and the division of a cell and the growth of the daughter-cells may not take more than twenty-four hours. Furthermore, increase in the number of cells is not an arithmetic but a geometric progression, and if, under favorable conditions, each daughter-cell divides once in twenty-four hours, it will give rise to an immense number of cells in a few days' time. This theoretical increase in the number of plants is not usually found in nature, but at times observations like those of Huff ('16), which are shown in Table I, show a very close approximation to it. The organisms studied (*Synedra*) are shown on Plate 23, Figures 21-23. These results show,

TABLE I. *Showing the daily increase in number of cells of Synedra pulchella present in successive days. (After Huff).*

Date	Individuals per c.c.	Date	Individuals per c.c.
Aug. 19	46	Aug. 24	225
" 20	80	" 25	520
" 21	111	" 26	1,080
" 22	300	" 27	3,020

therefore, that there is nothing in the rate of multiplication to prevent the accumulation of algae in sufficient quantities to be considered a bloom. In general, limiting factors check the unlimited growth of algae and, as will be shown below, the chemical composition of the water, light, temperature, shape of the lake, and other factors operate to facilitate or retard their growth.

The Algae That Cause Blooms. It has already been indicated that there are many different kinds of algae. The primary divisions of the fresh-water algae are based on the coloring matter within the cells or on the nature of the cell walls. These divisions of the algae are: the Myxophyceae or Blue-Green Algae, which contain a mixture of blue and green coloring matters; the Chlorophyceae or Grass-Green Algae, which contain only green coloring matter; the Heterokonteae or Yellow-Green Algae; the Phaeophyceae or Brown Algae; and the Bacillarieae or Diatoms, which have a cell wall that is heavily impregnated with silica.

Algae of all five classes are found in the plankton, and when the list of those which have been noted to occur in sufficient quantity to color the water is compiled it makes a much larger number of species than has generally been supposed. The following list comprises the algae that have been observed as producers of blooms at various times and in different parts of the world.

List of Algae That Have Been Observed To Produce Blooms.

Myxophyceae

Coelosphaerium Kuetzingianum
Amberg ('03), Farlow ('80, '83), Klebahn ('96), Kolkowitz ('10), Nelson ('03), Richter ('94), Schröter ('97), Wesenberg-Lund ('04).

Coelosphaerium dubium
Lemmermann ('08), Schmula ('98).

Coelosphaerium Naegelianum
Bachmann ('08, '10), Lemmermann ('07b).

Microcystis flos-aquae
Lemmermann ('07b), Richter ('94), Wesenberg-Lund ('04).

Microcystis ichthyoblabe
Lemmermann ('07b), Seligo ('90).

Clathrocystis aeruginosa
Farlow ('80, 83), Henfrey ('56), Klebahn ('95, '96), Kolkowitz ('10), Krause ('05), Lemmermann ('07b, '08), Ludwig ('96), Magnus ('83), Möbius ('07), Quelle ('07), Schneider ('08), Schröter ('97), Seligo ('90), Treichel ('79), Wesenberg-Lund ('04).

Polycystis scripta
Klebahn ('96), Magnus ('83), Richter ('94).

Polycystis prasina
Klebahn ('96), Magnus ('83), Richter ('94).

Polycystis ochracea
Brand ('98), Lemmermann ('07b).

Microcystis elabena
Lemmermann ('07b).

Microcystis viridis
Lemmermann ('07b).

Spirulina Thompsonii
Thompson ('40).

Oscillatoria aerugescens
Drummond ('83).

Oscillatoria prolifica
Hyams & Richards ('01, '02), Olive ('05).

Oscillatoria rubescens
Anonymous ('09), Bachmann ('01, '08, '10), Brehm & Zederbauer ('06a, '06b), Chodat ('96), Dakin & Latarche ('13), Heuscher ('02), Kolkowitz ('09, '10, '14a, '14b), Lemmermann ('07a, '07b), Lozeron ('02), Möbius ('07), Richter ('94), Schröter ('97), Zacharias ('02).
Nodularia spumigera
Francis ('78), Kolkowitz ('10), Richter ('94).
Trichomorus flos-aquae
Dickie ('40).
Anabaena affinis
Lemmermann ('07b).
Anabaena affinis var. *holsatica*
Lemmermann ('07b).
Anabaena catenula
Amberg ('03).
Anabaena circinalis
Amberg ('03), Cohn ('77), Klebahn ('96), Lemmermann ('07b), LeRoux ('07), Ludwig ('96), Nelson ('03), Phillips ('80), Richter ('94), Schmidt ('99), Schneider ('08).
Anabaena flos-aquae
Allmann ('55), Bachmann ('08), Bally ('08), Brand ('98), Farlow ('80), Forel ('02), Huitfeld-Kaas ('06), Klebahn ('96), Kolkowitz ('10), Lemmermann ('07b), Magnus ('83), Möbius ('07), Nelson ('03), Quelle ('07), Richter ('94), Schmidt ('99), Schneider ('08), Schröter ('09), Wesenberg-Lund ('04).
Anabaena Hassallii var. *cyrtospora*
Wittrock ('82).
Anabaena Lemmermanni
Bachmann ('08), Lemmermann ('07b).
Anabaena Levanderi
Schneider ('08).
Anabaena macrospora
Wesenberg-Lund ('04).
Anabaena macrospora var. *robusta*
Lemmermann ('08).
Anabaena spiroides
Wesenberg-Lund ('04).
Nostoc carneum
Quelle ('07).
Nostoc flos-aquae
Treviranus ('40).
Nostoc Linkia
Klebahn ('95).
Aphanizomenon flos-aquae
Ahlborn ('95), Kolkowitz ('09, '10), Lemmermann ('07b), Ludwig ('96), Magnus ('83), Morren ('38), Nelson ('03), Richter ('94), Schmidt ('99), Wesenberg-Lund ('04), Wittrock ('82).
Aphanizomenon recurvum
Thompson ('40).
Byssus flos-aquae
Linnaeus (1737).
Echinella articulata
Phillips ('80).
Gloeotrichia natans
Seligo ('90).
Gloeotrichia echinulata
Dickie ('40), Howe ('03), Klebahn ('95, '96), Kolkowitz ('10), Lemmermann ('07b), Plümecke ('14), Richter ('94), Schmidt ('98), Schröter ('97), Zacharias ('95b), Zykoff ('04).
Rivularia fluitans
Arthur ('84), Cohn ('78), Farlow ('84), Richter ('94).

CHLOROPHYCEAE

Carteria cordiformis
Zacharias ('02a, '03).
Chlamydomonas sp.
Hollis ('03), Whipple ('00), Zacharias ('03).
Chlomydomonas Reinardii
Kolkowitz ('10).
Sphaerella nivalis
Kolkowitz ('10).
Haematococcus pluvialis
Kolkowitz ('10).
Eudorina elegans
Kolkowitz ('10).
Volvox sp.
Schröter ('97).
Volvox aureus
Kolkowitz ('10).
Volvox minor
Zacharias ('05).
Volvox globator
Drummond ('95), Kolkowitz ('10), Seligo ('90), Thiebaud and Faure ('09), Zacharias ('05).
Pandorina morum
Forel ('02), Kolkowitz ('10).
Protococcus roseo-persicus
Klausener ('08).
Protococcus botryoides
Zacharias ('03).
Chlorella vulgaris
Zacharias ('02).
Westella botryoides
Zacharias ('02a).
Golenkinia radiata
Chodat ('94), Kolkowitz ('11).
Tetraedron papilliferum var. *tetragona*
Zacharias ('02b).
Scenedesmus quadricauda
Zacharias ('03).
Pediastrum Boryanum
Zacharias ('02b).
Cosmarium suevicum
Kirchner ('02), Klunzinger ('01, '02).

HETEROKONTEAE

Botryococcus Braunii
Amberg ('03), Chodat ('96, '98), Huitfeld-Kaas ('06), Klebahn ('96), Schröter ('97).

BACILLARIEAE

Melosira granulata
Kolkowitz ('10).
Stephanodiscus Hantzschianus
Kolkowitz ('10).
Asterionella formosa
Kolkowitz ('10).
Tabellaria fenestrata
Lozeron ('02).
Diatoma tenue var. *elongatum*
Zacharias ('03).
Synura acus
Zacharias ('03).

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Physical and Chemical Factors Affecting the Growth of Blooms. Since the organisms causing the blooms in lake waters are plants, they are governed in a general way by the same factors that govern the growth of plants on land. It follows, therefore, that a given volume of water can support only a certain number of plants in the same way that a given area of land will support only a certain plant population. In water as on land, when there is an abundance of food materials there will be a greater crop of plants.

Light and Chemical Relations. One of the primary conditions for growth of plants is light, since it is through the agency of light that the plant is able to carry on the process of photosynthesis, or the combination of carbon dioxid and water into the food essential for growth. It is well known that in water there is a considerable absorption of light as it passes downward. The results of Pietenpol ('18) show that the amount of light absorbed varies from lake to lake, that of lakes with a brown color or marsh stain being much greater per unit of depth that that of a clear-water lake. There is also a differential absorption of the various colors of the sun's spectrum, absorption of red rays being greater than that of the blue rays in lakes with clear water, while the reverse is true in lakes with dark waters. For all practical purposes the formation of new plants is correlated with the formation of food materials. This zone in which food manufacture may take place, the zone of photosynthesis, has been estimated by Birge and Juday ('11) as ten meters thick in clear-water lakes, and two to three meters thick in highly colored or turbid lakes.

Although light is essential for the growth of algae, very intense light may not be favorable. When attempts are made to grow algae under cultural conditions it is frequently necessary to place them in diffuse light, since they are killed by the direct rays of the sun. This direct killing effect of the sun's rays may be of much greater importance than has been suspected, and may account for the fact that the surface of a lake frequently contains fewer algae than the region just below the surface. This effect of the intensity of the sun's rays has been noted by Fritsch ('07) in a discussion of the algal flora of Ceylon, and he suggests that the great predominance of blue-green algae in the tropics may be due to a protection of the green coloring matter from the intense light by the blue coloring matter.

The amount of light falling upon any lake and passing some distance into the water is generally sufficient to cause a great development of algae, so that the amount of raw food materials present is the primary factor that determines the abundance or scarcity of development of the phytoplankton. Carbon dioxid is consumed in the process of photosynthesis, and the scarcity or abundance of plankton organisms is directly proportional to the amount of this compound that is available for carbohydrate food manufacture. Carbon dioxid exists in lake water in a dissolved state, and when it has been withdrawn by the activity of the plant it must be replenished either from the air, by surface waters flowing into the lake, by respiration of living organisms within the lake, by decomposition of organic matter, or from the dissolved bicarbonates of calcium and magnesium. The first mentioned sources are of but little importance, and the major portion of carbon dioxid comes from the last two sources mentioned. The amount of carbon dioxid present in solution varies in different lakes. It may be present in the form of free carbon dioxid that is readily soluble in water, or it may exist in union with other substances in two different states: either as the normal carbonate of calcium or magnesium ($CaCO_3$ or $MgCO_3$), which is known as the fixed or combined carbonate; or in the form of a bicarbonate ($CaCO_3.H_2CO_3$) where a part of it is in such a loose chemical union that it may be utilized by algae in their photosynthetic work. The extensive work of Birge and Juday ('11) on the dissolved gases of lake waters shows that under midsummer conditions the free carbon dioxid of the upper zone, the zone of photosynthesis, is frequently entirely used up, and as there is no source aside from the free carbon dioxid, algal growth ceases. This presence or absence of free carbon dioxid can be determined by phenolpthalin, an acid reaction indicating its presence and a neutral or an alkaline reaction indicating a deficiency. There is, as has been indicated above, a potential source of raw food material in the supply of half-bound carbonates in the water. This supply is not constant in all lake waters but is directly proportional to the hardness of the water since, at the time when the algal growths draw upon it, the amounts of the fixed and half-bound carbon dioxid in the water are equal. An index of the amount of potential supply may be made, therefore, by a determination of the fixed carbon dioxid. When such determinations are made all gradations are found from very soft waters with less than 5 c.c. of fixed carbon dioxid per liter, through medium hard lakes with 6–22 c.c. per liter, to hard-water lakes with more than 23 c.c. per liter. Since medium- and hard-water lakes have this greater potential supply of carbon dioxid it is not at all surprising to find in computing the plant population in different types of lakes that those with soft waters have a much smaller total bulk of plankton than do those with medium and hard waters. The mass of material available for photosynthesis is not, however, the sole regulating factor, for other chemical relations have an influence upon the growth of algae, but these are much more uncertain.

Another method of approaching the conditions under which algae grow is that of studying carefully controlled laboratory cultures, where the different chemical factors can be modified to suit the wish of the investigator. The literature on the subject of pure cultures will be found in the papers of Rayss ('15) and Vischer ('19). This promising field, particularly with reference to the blue-green algae, has not been developed to the fullest, primarily because of technical difficulties in the way of cultivating blue-green algae. Pringsheim ('13) has carried on experiments with blue-green algae, which unfortunately were not plankton species, under conditions of pure culture, and finds that as far as the nitrogenous nutrition is concerned the blue-green algae may use either ammonia, nitrites or nitrates as the source of nitrogen. He also investigated a large number of organic nitrogenous compounds as sources of nitrogen but found that they were of little use to these algae. This latter is of great importance because it is a well-known fact that blue-green algae grow best in waters that are slightly contaminated, and the more frequent occurrence of blooms as a region becomes more settled and as swamp or town drainage enters adjacent lakes, has been pointed out quite frequently. Up to a certain point it is undoubtedly true that a greater supply of nitrogen favors the growth of algae, particularly the blue-green algae.

The general opinion until recently has been that blue-green algae can make use of disintegration products in water and that their luxuriant growth in stagnant waters is due to the considerable amount of nitrogenous organic matter present. Pringsheim's investigations show that these organic substances are not a source of food, and that the blue-green algae grow in spite of them and not because of them. It is because blue-green algae are able to grow under conditions where other algae will not survive, especially in waters that are poor in oxygen, that they are found in lakes rich in organic matter.

Temperature. Another factor influencing the growth of algae is that of temperature. During the cold months of winter the temperature of the water is such that there is usually but little growth of algae, but with the warming during the spring months there arrives a condition favorable for their growth. With the cooling off of the lake under fall conditions the temperature of the water again becomes unfavorable. In general, optimum temperatures for the growth of the different classes of algae are different. The diatoms (Pls. 23-24) generally have two periods of maximum growth, one in the spring and another in the fall. Although other factors influence their growth, temperatures between 50° and 60° F. are found when they are most abundant. The relation of the grass-green algae (Pls. 7-22) to temperature is less certain, but their optimum is somewhere between that of the diatoms and that of the blue-green algae. Temperatures favorable for the growth of grass-green algae generally occur twice a year in the periodic temperature cycle of lakes, but large growths of these algae are usually found only in the late spring or early summer, possibly because the gas content of the lakes is not right in late summer when temperatures are also favorable. Broadly speaking, the blue-green algae thrive best at summer temperatures. Wesenberg-Lund ('04) finds that in the case of the filamentous blue-green algae (Pl. 4, Figs. 3-6) there are rather close limits for the various species found in Danish lakes, and that certain species are most abundant when the temperature is 16-18° C. while others reach their maximum growth at 18-22° C. He maintains that temperature plays an important role in blooming, and that those species that require warm midsummer temperatures of the water for maximum growth do not appear in quantity in cool summers when the temperature of the water does not rise above 18° C. Not all blue-green algae, however, reach their maximal development at high temperatures, the most notable exception being the alga which produces the "Burgundy bloom" in Swiss lakes at a temperature near the freezing point, and which disappears as soon as the water becomes warmer (Bachmann, '10; Lozeron, '02; Schröter, '97).

ECOLOGICAL RELATIONS OF THE PHYTOPLANKTON OF THE PARK

The Nature of the Plankton Flora. Before considering the ecology of the phytoplankton in the Park, attention should be called to the fact that the phytoplankton forms a definite plant association and not an accidental heterogeneous collection of algae that grow in mid-lake. In a collection of algae from mid-lake the greater part of the individuals are those to be found only in the plankton and not in the shore flora; there are, however, a small proportion of shore forms that have drifted out into the open lake. The former have been called the eulimnetic phytoplankton and the latter the tycholimnetic. There is still another group of algae which thrive equally well under shore (benthitic) or true plankton (pelagic) conditions, and for which I have suggested the name: facultative planktonts, ('20).

Recognition of the distinctive nature of the eulimnetic plankton community is necessary, since many investigators in discussing the origin of the plankton constituents of a reservoir or an artificial lake assume that the "seeding" comes from the algae associated with the vegetation of swamps or streams draining into a lake.

Chroococcus limneticus (Pl. 3, Fig. 1), *Sphaerocystis Schroeteri* (Pl. 7, Fig. 2), *Trichodesmium lacustre* (Pl. 4, Fig. 3), various *Anabaena* species (Pl. 4, Figs. 4-6), the Micractinieae (Pl. 9), or certain of the Desmidiaceae (Pls. 13–22) may be cited as examples of eulimnetic organisms. In all of these, flattened colonies, curving of the filament, gelatinous bristles and the like, are adaptations for the free-floating life. These peculiarities of pelagic algae have been discussed by W. & G. S. West ('09) and Lemmermann ('04) and the conclusion is reached that a character like curving of the filament does not occur whenever an organism is transferred to pelagic conditions but is found only in those filamentous species that have been living under pelagic conditions for some time. On the other hand, in the case of the tycholimnetic algae, of which *Tetraedron muticum* (Pl. 8, Fig. 4), *Scenedesmus obliquus* (Pl. 11, Fig. 6), and *Closterium Kuetzingii* (Pl. 13, Fig. 7) may be cited as examples, we have algae which are not adapted to the free-floating life, and which do not multiply when they are accidentally carried to mid-lake. The reason for certain algae living in mid-lake and others finding it an unfavorable environment is probably in the greater buoyancy of the eulimnetic algae. The problem of buoyancy is the chief one for the pelagic organism, and this problem is all the more complicated since the viscosity of the water varies at different times of the year, and the organism must meet these changes in viscosity. Ostwald ('02, '03) has discussed at length the physical-chemical changes of water at different temperatures; while Wesenberg-Lund has observed the changes of length of cell in colonial diatoms to meet this varying environmental factor.

The facultative planktonts are best represented by several of the *Pediastrum* (Pl. 12), *Scenedesmus* (Pl. 11), and *Merismopedia* (Pl. 3, Figs. 4–6) species. These algae are frequently found in collections from pools and ditches, but are also found in sufficient quantity in plankton collections to show that they reproduce under pelagic conditions.

Although students of the phytoplankton recognize its distinctive nature they are at considerable variance on the question of its relation to the size and shape of a lake. Zacharias ('98) has proposed the term heleoplankton to describe the plankton community of a pond in contradistinction to the limnoplankton of a lake. He states that certain small bodies of water have a rather constant eulimnetic flora whereas the same species are only of sporadic occurrence in large bodies of water. G. S. West ('16) also recognizes the heleoplankton formation, citing the Micractinieae as examples of algae that are of more frequent occurrence in ponds than in lakes. In certain regions of North America, the distinction between a limnoplankton and heleoplankton flora is quite sharp, but in the area under consideration these distinctions are not evident.

The physical distinction between a "pond" and a "lake" cannot be made with certainty. There have been several attempts to characterize bodies of water upon morphometric bases, but if such distinctions are to be made they must rest upon the basis of depth.

This differentiation based upon depth should not be upon some arbitrary depth but upon the basis of thermal stratification. If ponds are defined as bodies of water without thermal stratification we find that most of the waters of the Park region are of the pond type; Mombasha, Popolopen and Island Lakes being the only true lakes. On the basis of quantitative distinctions between the heleoplankton and the limnoplankton my observations agree with those of Whipple ('14) and Huitfeld-Kaas ('09) who hold that shallow bodies of water produce proportionally greater masses of plankton, instead of those of W. & G. S. West ('04, '09) who state that the plankton production is generally greater in large lakes. As has been shown above, environment plays an important role, but other things being equal shallow lakes have a greater bulk of plankton.

Attempts have also been made to classify the plankton flora on the basis of the constituent organisms and without particular reference to morphometric considerations. The first of these attempts, that of Apstein ('96), divides the lakes into the *Chroococcus* and *Dinobryon* types. The former are characterized by numerous Chroococcaceae (Pl. 3), comparatively few *Dinobryon* colonies (Pl. 5, Fig. 7), and a general quantitative richness of the phytoplankton; the latter have few Chroococcaceae, numerous *Dinobryon* colonies and clear waters, owing to the small bulk of the plankton. Many have objected to this system of classification and have cited lakes that fail to conform to Apstein's system of classification. Amberg ('00), Huitfeld-Kaas ('06) and Plümecke ('14) have shown lakes where this classification breaks down. G. S. West holds that Apstein is fundamentally correct in making a distinction between different types of plankton floras, but his division is not sufficiently far-reaching, especially in view of the desmid type of plankton formation. Lakes with a rich desmid flora were first discovered in Scotland by W. & G. S. West ('03), but they are now known to exist in the Scandinavian peninsula (Huitfeld-Kaas, '06; Teiling, '16; Strom, 21), Ireland (W. & G. S. West, '02, '03), Africa (G. S. West, '07), Australia (G. S. West, '09) and North America. This plankton flora, in which desmids form a conspicuous feature, has been called the Caledonian plankton formation by Teiling ('16) in contrast to the Baltic type where there are few desmids. In contrast with these views Wesenberg-Lund ('08) holds that the plankton community contains the same types everywhere, and nearly everywhere the same species, and that attempts fail when they try to divide these organisms into phytogeographical communities, since there are no sharply delimited areas of distribution of certain species or genera. The sharply defined Caledonian formation that W. & G. S. West have noted is clearly discernible in certain lake areas of the United States; and Teiling's two classes — the Caledonian with a conspicuous desmid content, and the Baltic with a rich blue-green algae content — should be recognized. The distribution of *Dinobryon*, and for that matter of other plankton Phaeophyceae (Pl. 5) does not follow definite rules; they may constitute an important portion of either the Baltic or the Caledonian associations or they may be lacking. On the other hand the Baltic community has a relatively large proportion of Myxophyceae, while the Caledonian contains a small proportion of these algae. In view of the foregoing it seems unadvisable to attempt a subdivision of the Baltic association, but more logical to regard it as constituting a formation of somewhat varying qualities in which Myxophyceae are always present.

Relation of the Plankton Formations to Geological Conditions. In their first article calling attention to the Caledonian formation W. & G. S. West do not offer an explanation of the phenomenon. Two years later ('05) they suggest that the occurrence of numerous desmids in the plankton is due to the correlation between desmid distribution and geological formation, a correlation which Wittrock had previously pointed out. They state that the waters draining into lakes rich in desmids are peaty and slightly acid; this may produce a favorable medium for the growth of desmids but does not account for the richness in species. They then go on to show that while lakes in Carboniferous areas may receive peaty waters they are relatively poor in desmids, and that lakes in Secondary or Tertiary geological formations are even poorer in desmids. From this they conclude that the diversity of species in the desmid flora is directly correlated with the geological antiquity of the region, while abundance of individuals is due to the absence of lime and the presence of humic acids. They have also investigated the phytoplankton of other regions (W. & G. S. West, '06, '09a, '09b; and G. S. West, '07, '09), and in every case in the discussion of the flora call attention to the correlation between richness in desmids and old geological formations. In their article summarizing the phytoplankton of Great Britain ('09) they take up the distribution of British desmids in general, and show that eastern England is poor in species but that the western part contains areas very rich in species. They hold that two factors are essential for an abundant desmid flora,— a geological formation older than the Carboniferous, and an abundant rainfall. If either of these factors is lacking a region will not contain numerous desmids. This is shown in a striking manner by their map of Great Britain, which gives the distribution of rainfall, geological areas, and abundance of desmids. Turning to the phytoplankton they state that lakes lying in rich desmid areas are usually rich in plankton desmids, the same factors that favor a general development of desmids favoring the occurrence of plankton desmids.

This hypothesis of geological correlation has not been allowed to pass unchallenged, and other explanations have been offered to account for the predominance of desmids in the plankton of Great Britain. In a comparison of Scotch and Danish lakes, Wesenberg-Lund ('05a, '05b) thinks that the peaty character and richness in humic acids are the factors favoring the growth of desmids. In a later paper he develops the idea ('08) that desmids are richest where the water is derived from bogs and mossy slopes, but that when these conditions give place to heaths, plains, and arable lands the desmids are less numerous. He also agrees with Bachmann ('08) that the antiquity of the country does not matter, because the whole of Scotland was covered with ice during the last glacial invasion so that "the high geological age cannot be taken into consideration for the development of plankton desmids." W. & G. S. West ('09) have replied to this by pointing out that desmids thrive in spite of and not because of peaty conditions, and that the majority of British desmids grow best in clear water with but little peat.

Murray's ('05) reason for denying the geological theory is that Scotch lakes of the Caledonian type lie in geological formations varying from the Lewisian to the Tertiary. He seeks a climatic explanation, holding that the ocean influences the temperature and rainfall of lakes to such an extent that the "western type" of desmid is found only in eastern North America and western Europe. In replying to Murray's views W. & G. S. West state that what he calls "Tertiary lakes" are situated in drainage basins drawing their waters from the older geological formations.

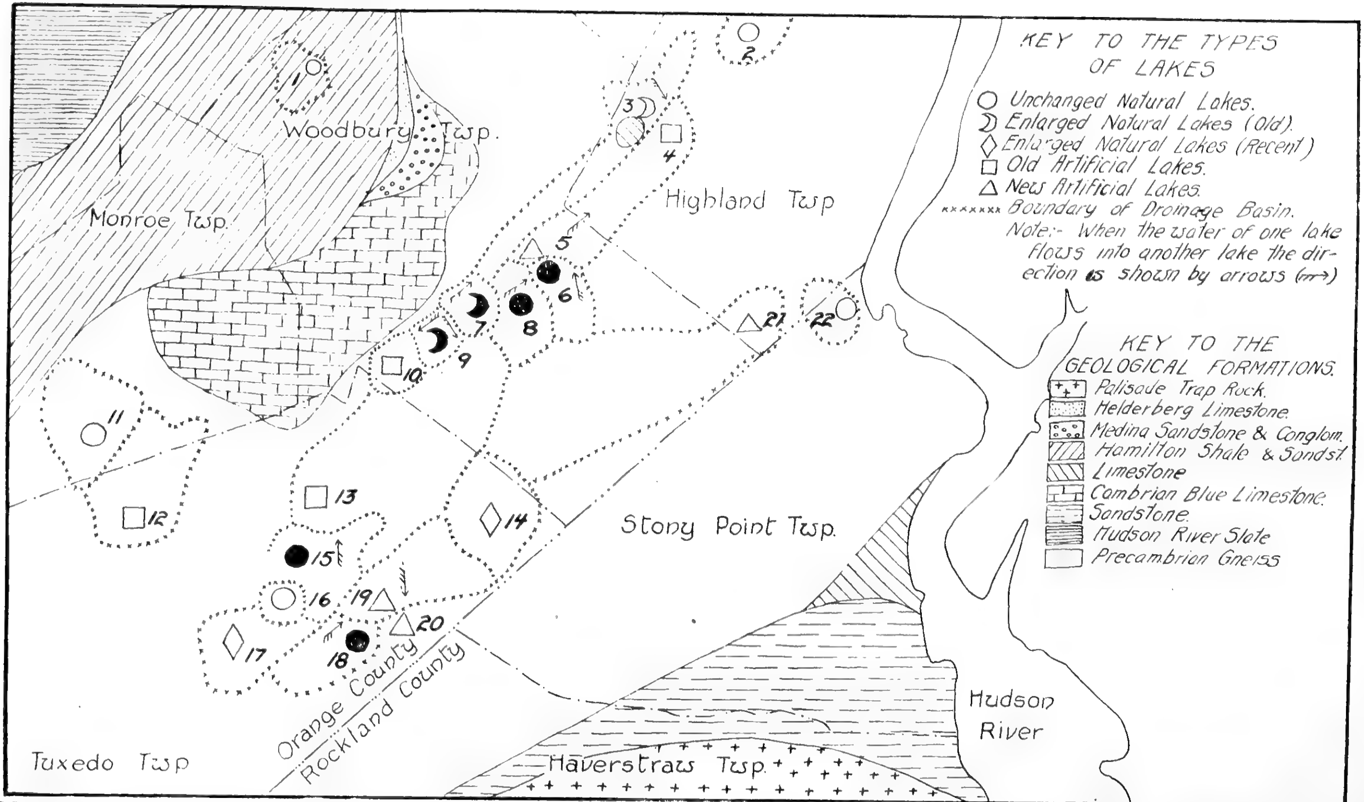
In comparing Swiss and Scotch lakes Bachmann ('08) is the first to make the point that geological antiquity is of little importance as the whole of Scotland was buried under ice during the recent glacial epoch. He holds that lime is not the factor controlling the distribution of desmids, since Loch Balnagan on the Isle of Lismore has a desmid flora and this whole island is composed of limestone. Bachmann's explanation for the occurrence of desmids in any region rests upon the chemical nature of the drainage from peaty swamps. He thinks that careful chemical analyses will show certain chemical compounds favoring the growth of desmids. He agrees with an earlier expressed view of Chodat ('97) that smaller lakes have a richer desmid flora. This correlation of lake size and desmid frequency has been denied by W. & G. S. West, who state that Bachmann's generalization is based upon insufficient knowledge of Scotch lakes, as some of the largest lakes have the richest desmid flora ('09b).

My investigations of the phytoplankton of lakes in Wisconsin, Ontario, and the Palisades Interstate Park region corroborate completely the view of W. & G. S. West that geological conditions are the prime factors controlling the distribution of plankton desmids. Wisconsin offers an excellent field for testing the hypothesis, since the lakes in the southern part of the state lie in a limestone and sandstone region while the northern part of the state is Archaean. Furthermore, all the lakes are glacial in origin, those of the north having been formed by the Late Wisconsin glacial invasion and those of the south by earlier invasions. These lakes of both regions are of practically the same age but have quite different floras. Caledonian associations are of frequent, though by no means universal, occurrence in northern Wisconsin; southern Wisconsin lakes, with one exception, belong to the Baltic type. The factor governing the distribution of desmids is not the antiquity of the lake but the chemical nature of the water. The most striking instance of this is Devil's Lake in southern Wisconsin, lying in a small quartzite area that is surrounded on all sides for many miles by sandstones and limestones. Desmids are an important part of the flora of this lake and its flora is of a true Caledonian type, while all of the other lakes of the surrounding region that lie in limestone basins belong to the Baltic type. The occurrence of desmid lakes in northern Wisconsin is quite irregular, and it is impossible to predict that any given lake lying in this old geological region will contain desmids. The reason for the "spotty" distribution of lakes of the Caledonian type probably lies in the fact that the old rocks are covered by a mantle of glacial drift 25 to 400 feet thick which is quite variable in character. In the portions of Ontario where I have studied the phytoplankton, the Caledonian formation is of uniform occurrence and it is interesting to note that in this region the mantle of glacial drift is very thin, so that large areas of the underlying country rock are exposed.

The Caledonian plankton association has certain other characteristics besides a predominance of desmids. In their studies of the Scottish lakes both Wesenberg-Lund ('05) and W. & G. S. West ('03, '05) comment upon the small volume of the plankton. This plankton association is also characterized by the small proportion of blue-green algae, both in shallow and deep lakes, while the number of species of Protococcales found in these lakes is much smaller than that in lakes of the Baltic type.

Among the lakes of the Palisades Park region certain of them have a flora that is distinctly of the Caledonian type. Little Long Pond is probably the best example of such a formation and among the eulimnetic organisms found in it are several *Staurastrum* species (Pls. 17–21), *Micrasterias* (Pls. 14–16) and various filamentous Desmidiaceae (Pl. 22). The blue-green algae are very poorly represented, and while colonies of *Coelosphaerium* (Pl. 3, Figs. 7–8) and *Anabaena* (Pl. 4, Figs. 4-6) have been observed, *Chroococcus limneticus* (Pl. 3, Fig. 1) is the member of the Myxophyceae that occurs in numbers. In the same way the Protococcales are of minor importance, *Quadrigula Pfitzeri* (Pl. 10, Fig. 6) being the only species of importance. Other lakes of the Caledonian type in this region are Upper and Lower Twin, Summit, and Forest Lakes.

The distribution of the Caledonian type of lakes in the Park region is shown on Map 2, which also shows the relation of these lakes to the geological substratum. All of the lakes of this type, as well as their drainage basins, lie in the Precambrian gneiss while the two lakes that drain from the limestone region do not have a desmid flora. The fact that there are such natural lakes with a lack of blue-green algae and Protococcales in the Park region is of the utmost importance, since such lakes practically never produce blooms that impair their usefulness. Long Pond, Lake Mombasha, and Hessian Lake, all natural lakes situated in the Precambrian gneiss, are apparently of the Baltic type. The geological survey upon which this



Map. 2. The Park region, showing relation of the type of plankton flora to the geological formations. Lakes of the Caledonian type are shaded, those of the Baltic type are unshaded. The lakes are: 1, Cromwell; 2, Long; 3, Popolopen; 4 Mine; 5, Barnes; 6, Lower Twin; 7, Summit; 8, Upper Twin; 9, Forest; 10, Cranberry; 11, Mombasha; 12, Little Dam; 13, Echo; 14, Cedar; 15, Island; 16, Green; 17, Stahahe; 18, Little Long; 19, 20, Kanahwauke; 21, Queensboro; 22, Hessian.

map is based is more in the nature of a reconnaissance survey than a thorough examination of the region, and it may be that there are other small patches of sedimentary rocks like that near Popolopen Pond. That there may be factors influencing the chemical composition of the waters of these lakes that do not have a rich desmid flora is suggested by the occurrence of blue-green algae in considerable quantity in Mombasha Lake and Long Pond.

In seeking for an explanation for the correlation of the desmid type of lake with the geological formations of a region W. & G. S. West have commented upon the absence of lime. Calcium and magnesium seem to me to be important factors governing the distribution of desmids. Unfortunately the artificial cultivation of desmids is extremely difficult, and there are no accurate data on the mineral requirements of the family as there are in the case of the other algae. The only investigation on the subject, that of Andreesen ('09), sheds little light on the inorganic salts required by these organisms. The analyses of lake waters in this region show that the mineral content is low (Table 2) and that the lakes

TABLE 2.—*Analyses of lake water in the vicinity of the Park.*
(From the Reports of the New York State Department of Health.)

	PARTS PER MILLION			
	Cedar Pond Reservoir	Lake Mombasha	Cromwell Lake	Bog Meadow Pond (near Long Pond)
Total solids	74.	45.	46.	25.
Loss on ignition	20.	16.	6.	14.
Mineral residue	54.	29.	40.	11.
Free ammonia	.018	.054	.022	.004
Albuminoid ammonia	.052	.090	.110	.144
Total hardness	33.8	16.9	23.4	4.8
Alkalinity	33.	8.	11.	3.

should support a small plankton population in case of the one old lake from the Precambrian region, while Mombasha and Cromwell Lakes have more mineral matter. The sample from Cedar Pond was taken from Cedar Brook some distance below Cedar Pond, and may not represent the condition in the Pond.

The absence of lime may be the factor which favors the development of desmids, but this absence of lime does not show why, from the qualitative standpoint, the Caledonian association contains so few representatives of the blue-green algae nor why, if a lake will support a certain number of these Myxophyceae, they are practically all Chroococcaceae and not equal numbers of all plankton genera. Temperature has been suggested as the factor limiting the production of blue-green algae in the British lakes, but the temperature of the Park lakes is the same as that of other lakes of the region where Myxophyceae are found in abundance, so that we cannot ascribe a dearth of these organisms to low temperatures. Lack of nitrogenous compounds may be a factor since it is well known that when waters are even slightly contaminated by drainage from a settled area there is a very considerable increase in the blue-green content of the plankton.

Seasonal Succession of the Plankton Algae. This discussion of the plankton constituents of the Park lakes may have suggested that the flora is quite constant in lakes of the Caledonian type or that the flora is constant from month to month. On the contrary each lake of the Caledonian type has a distinctive flora, certain species predominating in one lake and other species in another lake. There is likewise a variation of the flora as the season progresses. This seasonal variation of the flora has been noted by every investigator who has followed the biological history of a lake for a year, and the spring maximum of diatoms, sometimes followed by a second autumnal maximum; an early summer maximum of Chlorophyceae and a late summer and early fall maximum of Myxophyceae are well known to all. These regular seasonal successions are found in all parts of the world, although a lake in the southern hemisphere would have midsummer conditions in February and March (G. S. West, '09). Since the observations on the Park lakes were carried on from July 1 to September 1 the complete seasonal succession was not observed, although the normal changes which were to be expected at that time were noted. In the case of the Caledonian plankton formation these seasonal changes were not very pronounced, chiefly because the blue-green algae did not increase at the end of the summer, a fact to which Wesenberg-Lund ('05) and W. & G. S. West ('05) have already called attention in their comments on conditions in Scotch lakes.

Algal Succession in Artificial Lakes. Although the natural lakes of the Park region have the characteristic low plankton volume and small blue-green content of the Caledonian community, the new artificial lakes have a quite different flora, blue-green algae occurring in sufficient quantity to be a troublesome pest. One of the primary objects of the investigation of these lakes was to obtain light on the problem of ecological succession in the plankton community of artificial lakes, and to see if there is any reason for expecting that artificial lakes will eventually reach the biological conditions found in the natural lakes of the region.

Miss Monti ('06) seems to have been the only investigator to take up this problem of ecological succession in a newly formed lake. Her investigations were made on small alpine glacial lakes which were about thirty-five years old when examined. The flora of these lakes was rather poor, consisting chiefly of diatoms and a few Protococcales. The Myxophyceae were not found at all, probably on account of the temperatures of the water, which, even under midsummer conditions, did not exceed 1 to 11 degrees Centigrade. The poverty of phytoplankton in these lakes makes it unsafe to draw any general conclusions from her results.

There have been, however, several studies that are of interest in shedding light on the nature of the plankton flora of artificial lakes. Griffiths ('09) finds that the flora of an old small artificial lake in England contains *Volvox* (Pl. 6, Fig. 8) and *Microcystis* (Pl. 3, Figs. 11–13) in small quantity, but thinks that this lake does not develop a true plankton flora. In a later investigation of other artificial lakes from the same region he finds a typical heleoplankton formation with the occurrence of certain Protococcales in considerable abundance.

G. S. West's thorough-going survey of the Yan Yean reservoir in Australia ('09) is of particular interest, since he finds a true Caledonian plankton community. This body of water was formed in 1857 when a dam thirty feet high was built across a valley to impound water for a municipal water supply. In this reservoir there are about 120 different organisms, and of these about four-fifths are found in the plankton only. The proportion of the frequency of the various species in the plankton and the benthos is not the same, since certain ones occasionally found in the benthos are undoubtedly accidental wanderers from the plankton where they occur in abundance. The great scarcity of blue-green algae in this comparatively shallow artificial lake is also a striking feature of the flora; and this artificial lake, with a typical lacustrine Caledonian flora that is practically free from blue-green algae, is particularly hopeful in showing that an abundance of blue-green algae is not a universal character of artificial lakes.

In the artificial "tanks" of Ceylon, Fritsch ('07) has found that the flora is practically that of a normal lake. In these waters the plankton is characterized by a luxuriant growth of blue-green algae, particularly *Microcystis,* a condition which is explained by the high temperatures and lack of aeration. Fritsch gives no data on the age of these lakes.

The most intensive study of an artificial lake is that of Kolkowitz ('09, '14) on the "Lietzensee" in Berlin. The site of this lake was originally a swamp, with the water 10 to 15 inches deep and filled with the common swamp plants. In 1904 this was dredged to an average depth of six feet to form an ornamental lake a hundred yards broad and eight times as long. Two years after the building of the lake there was a bloom with *Anabaena spiroides* predominating but accompanied by a small amount of *Oscillatoria Agardhii.* In the latter part of 1908 *O. Agardhii* appeared in quantity and since that time has always been found in great abundance during the late months of the summer. Kolkowitz thinks that the great amount of organic matter is the chief reason for the growth of *Oscillatoria.*

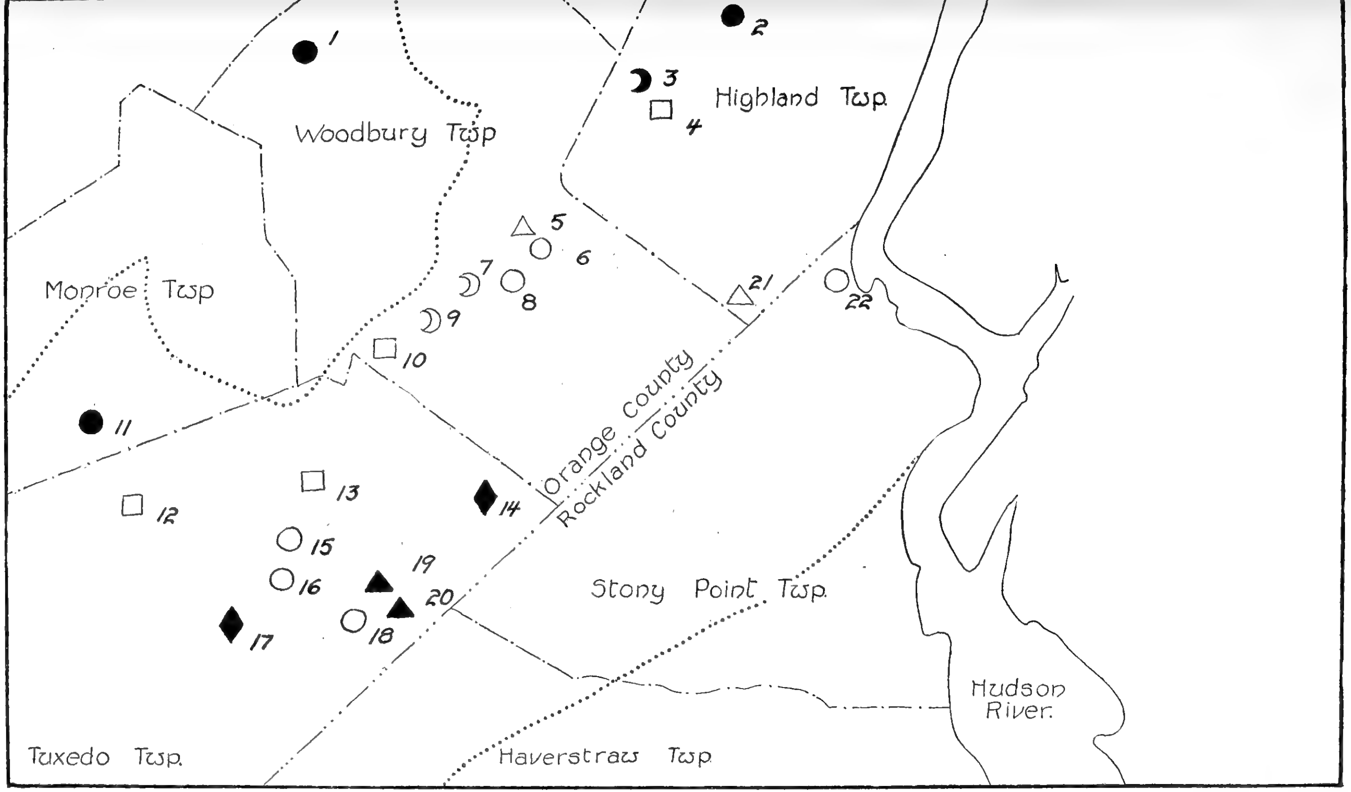
Kolkowitz also discusses the flora of a number of artificial reservoirs in Germany that are 5 to 15 years old ('11). In these the Phaeophyceae and Volvocales are the most common organisms, blue-green being present in some and lacking in others.

In the Palisades Park the flora of the artificial Kanahwauke Lakes and the artificially enlarged Stahahe and Cedar Lakes is characterized by a heavy growth of Myxophyceae. In the Kanahwauke

Lakes *Microcystis* dominates, in Stahahe Lake *Anabaena,* while in Cedar Lake the coloration of the water is caused by *Coelosphaerium.* Queensboro Lake, which was built at the same time, and Barnes Lake, just outside the Park boundaries, have not developed blooms of blue-green algae, although in the case of Queensboro Lake there is a large growth of *Eudorina* (Pl. 6, Fig. 7) and *Synura uvella* (Pl. 5, Figs. 2–3).

When these recently built artificial lakes that produce blooms are compared with the other artificial lakes of the region (Map 3) it will be noted that only one old artificially enlarged lake has a sufficient development of blue-green algae to come in the bloom class. In contrast to the conditions found in Popolopen Pond the flora of Mine, Cranberry, Echo, and Little Dam Lakes (all old artificial lakes), or Summit and Forest Lakes (old artificially enlarged lakes), is not characterized by a conspicuous development of blue-green algae. These lakes all lie in the belt of Precambrian rocks shown in Map 2. Two of these enlarged artificial lakes (Summit and Forest) are of the Caledonian type; the other shallow artificial lakes do not have a sufficient proportion of desmids to be called Caledonian associations. It does not seem unreasonable to assume that these lakes have reached a fair state of biological equilibrium, or that they have reached their normal lacustrine flora. If this is true it does not seem improbable that the flora of the new artificial lakes of the Park, which at present are producing large numbers of blue-green algae, will gradually undergo changes in nature, and when this flora arrives at a fairly constant state, making all due allowance for the fact that the plankton of a lake varies from year to year, it will be similar to that of other old artificial lakes of the region. These new artificial lakes all lie in a region (Map 3) where the stable lakes have the typical high desmid content and low blue-green development of the Caledonian plankton formation, and in all probability some of them will eventually arrive at a condition resembling Summit or Forest Lakes.

The cause of an intensive development of blue-green algae in newly formed reservoirs is a complicated problem involving a number of unsolved factors. Little Long Pond is a true desmid lake and one with very few blue-green algae. It might be a natural inference that if the water from this lake were collected in a new lake the plankton organisms in the new and the old lakes would be practically the same, since the old lake is continually introducing its algae into the new lake. In actual practice this has not been the result. Kanahwauke Lake was formed by damming the valley below Little Long Pond and impounding the water of its outlet. The plankton of Kanahwauke consists very largely of *Microcystis* (Pl. 3, Figs. 11–13) and Phaeoflagellates (Pl. 5), with only occasional desmids. The source of the waters in the two lakes is the same and so the explanation must be sought in the changes taking place in the nature of the water in Kanahwauke after its entrance into the lake. In the building of Kanahwauke Lake no attempt



Map. 3. The Park region, showing lakes that bloom and their relations to other lakes. Note that the old artificial lakes and the artificially enlarged lakes in the belt of precambian gneiss, whose boundaries are shown by dotted lines, do not bloom. The lakes that bloom are shaded; those that do not bloom are unshaded. Geological formations, symbols for different types of lakes, and numbers of lakes are as on Map 2.

was made to remove the soil or even the vegetation, the site being flooded without preliminary preparation as soon as the dam was completed. This undoubtedly makes the water of the lake much richer in organic matter than that of Little Long Pond, and this richness in organic matter, coupled with a higher content of inorganic salts due to the leaching of the soil, accounts for the changes in the nature of the water favoring the development of blue-green algae. In enlarging Carr Pond to form Stahahe Lake, and in joining the two Cedar Ponds to form Cedar Lake, there was no especial preparation of the lake bed. In the case of both of these lakes there were swampy tracts along the shore, and when the swamps were flooded on the filling of the lake large floating bogs developed. Nothing is known concerning the plankton flora before these lakes were enlarged, although the residents of the region report that the lakes did not bloom before they were enlarged. At the present time they bloom profusely, and this blooming has no doubt been accelerated by the abundance of decaying vegetable matter on the bottoms and shores of the lakes.

Origin of the Plankton Flora In a New Lake. Many students of the algal flora of artificial waters, especially the students of the biological problems involved in the building of artificial reservoirs, proceed upon the assumption that the organisms which will appear in these reservoirs all come from the immediate drainage basin and that swampy areas are centers from which " seeding " of the reservoir takes place. As has been shown above the plankton flora is a highly specialized one and in general the organisms constituting the major portion of the plankton community are not found in the shore regions. The source of many of the plankton algae of an artificial lake is not the drainage into the lake but some neighboring body of water that contains a true plankton flora. The migration of algae from place to place is a passive phenomenon, and may be brought about by the agency of air currents, insects, or birds.

The scanty observations on the subject of algal migration are concerned largely with the migration of nonplankton algae, and are based upon speculation rather than actual observation. Birds are considered the main agency causing invasion of algae into new regions by Wille ('97), Borge ('97) and Borgesen ('01). Their observations dealing with the Faeroes are of particular interest since the algae found in these islands must all have been carried there since the glacial epoch. The facts that aquatic birds fly from one body of water to another, and that algae might adhere to them, give a sufficient explanation if the algae are not killed by dessication during the journey. If spores are carried they are undoubtedly able to withstand the journey successfully, as G. Schröder ('86) has shown that resting spores of algae withstand drying for some years and then germinate. B. Schröder ('02) has observed that vegetative cells of algae have a considerable resistence to drying, and it may well be that the gelatinous envelope frequently surrounding plankton algae prevents a too great loss of water.

With these possibilities of new algae being introduced into the waters of the Park there is always the chance of new algae, and sometimes algae that will grow luxuriantly, appearing in the plankton flora. The extent to which these new algae will dominate the flora of a lake is, however, a matter of conjecture.

METHODS OF CONTROLLING ALGAL GROWTHS

Proper Construction of Artificial Lakes. Since the method of building the Park lakes has undoubtedly increased conditions favoring the growth of algae, remedial measures should be considered. The depth of a lake is of importance both in the way that it affects the fish and in the way that it influences the growth of algae. In the warm months the water of a deep lake is not of uniform temperature, but consists of an upper region where there is a vertical circulation of the water (the epilimnion) and a bottom region of stagnation (the hypolimnion). These two layers do not fuse gradually, but are separated by a sharply defined transition belt (the thermocline). The thickness of the epilimnion, or zone of circulation, depends upon the size of the lake, being about ten feet thick in small lakes and 30 to 40 in large ones (Birge and Juday, '11). This thermal stratification of the lake is accompanied by changes in the gaseous content of the different parts; Birge and Juday having shown that carbon dioxid, the gas essential for food manufacture by algae, tends to decrease in the epilimnion and to increase in the hypolimnion. The accumulation of carbon dioxid in the lower waters is of no particular advantage to the algae since the hypolimnion is generally at a depth below that where there is sufficient light for the effective utilization of the carbon dioxid by the algae. The increase in the carbon dioxid at the bottom of the lake comes from the decay of algae that are sinking from the surface as well as from the decay of other organic material at the bottom. In shallow lakes without thermal stratification there is a continuous circulation of the waters and their dissolved gases from top to bottom, so that the products of algal decay are immediately available for re-utilization. In addition, the carbon dioxid and other products from the decay of organic material at the bottom are also carried to where they can be utilized by the algae, and so shallow lakes in general support a proportionally greater mass of algal vegetation. In the construction of new lakes in the Park attention should be given to the question of the proper depth of lakes, since the inauguration of the policy of building shallow lakes with a depth of 8 to 12 feet will certainly invite a repetition of the experiences of algae in large numbers that have been encountered with some of the lakes already constructed. Artificial lakes with a depth of 30 to 40 feet, and an average depth of 15 to 20 feet, will undoubtedly be productive of less trouble from algae.

In addition to the problem of the proper depth of the lake attention should also be given to the preparation of the lake bed. Hazen and Fuller ('97) have made an exhaustive study of this problem in connection with the construction of the Ashokan and Kensico reservoir of the New York City water supply, the essential parts of which have been reprinted by Whipple ('14). They discuss the cases where all the soil has been stripped from prospective sites of reservoirs, and show that the removal of the earth reduces considerably the growth of algae but is not a sure preventive. In the case of the Park lakes constructed for pleasure purposes only, even more than in the case of reservoirs for municipal water supplies, the cost of this soil stripping is prohibitive. The object in soil-stripping is to eliminate a source of decaying organic matter that will furnish material for the growth of algae. This comes in part from the decay of vegetable matter, and conditions in a lake bed may be appreciably bettered by removing all plant growth. They recommended the clearing off and grubbing out of all trees in the proposed site and afterwards a burning off of all the vegetation. In the case of the lakes of the Park this careful removal of the vegetation is necessary for the utilization of the lakes by campers, since submerged stumps are a constant menace to those using the lakes.

The point at which the dam is to be built should also be taken into consideration. Too often the engineer, with his mind set solely on construction of a lake at a moderate cost, is tempted to select a flat swampy area since he can then make a large lake cheaply. In these swampy areas, however, there is a large amount of decaying vegetable matter and an enormous potential source of organic matter to supply food materials for the algae for many years to come. It is far better to choose a site where there are no swampy areas, and where the flooding of the lake bed will not produce one with swampy margins. If lakes are placed in valleys fairly free from low wet areas, made reasonably deep, and the beds are suitably cleared before flooding, there should be no excessive growth of algae.

Removal of Algae by Means of Chemicals. The discussion given above has adduced sufficient evidence, in my opinion, to warrant the conclusion that the artificial lakes or artificially enlarged natural lakes of the Park will eventually arrive at a state of biological stability where the plankton Myxophyceae will not grow in sufficient quantities to affect the use of the lakes as camp sites. Until these lakes develop the normal lacustrine habit of the region, however, disagreeable "blooms" are apt to occur and chemical means for their control should be used.

The development of algae in natural or artificial bodies of water used for municipal water supplies is of even greater importance because the presence of certain algae may affect the taste even when it does not affect the esthetic or recreational use of a lake. Methods for the control of algal growths have been developed primarily because of this fact. The current practice for the removal of algae rests upon the use of copper sulphate as introduced by Moore and Kellerman ('04, '05). At the time of the publication of Moore and Kellerman's method for eradicating algae a great deal of interest was expressed by sanitarians; and numerous reports of experience with the method are found in the periodical literature; but with the gradual adoption of filtration for municipal water supplies interest in algicides has decreased, and the literature of the past decade contains but few references on the subject.

The following discussion of the method is based in large part upon a study of the literature rather than actual experience, since the Park lakes produced but one "bloom" which required treatment during the summer of 1918, and this was composed of a single organism. Although the copper sulphate method is simple in theory it is complicated in application since it rests upon variable factors. Attention has been repeatedly called to the fact that each lake must be studied as an individual and the use of copper sulphate controlled by preliminary studies of the particular body of water to be treated. The variable factors that should be investigated in each individual case are: the volume of the lake, the particular organisms to be eliminated, the temperature of the water, the organic matter in solution, the temporary hardness of the water, and the amount of dissolved carbon dioxid.

The computation of the volume of water should rest upon accurate hydrographic maps which show, by means of contour intervals, the depths in the various portions of the lake. Birge and Juday ('14) recommended the formula of Penck for computing the volume of the different strata on a hydrographic map. In this formula s_1 is the area of the upper surface, s_2 the area of the lower surface of the section whose volume is to be determined, and h the vertical thickness of the stratum. The volume of the stratum (V) then is

$$V=\frac{h}{3}\left(s_1+s_2+\sqrt{s_1 s_2}\right).$$

This computation must be repeated for each contour interval, and the total volume of the lake obtained by combining those of the different strata. A rougher method for approximating the volume of a lake is given by Whipple ('14), who states that an acre of water three feet deep represents a million gallons of water. The approximate volume in millions of gallons may be calculated by multiplying the acres of surface by the average depth of the water and dividing by three. This, of course, involves making a number of soundings to determine the average depth of the lake.

Thermal stratification of deep lakes is a common occurrence in summer. In the warmer upper epilimnion there is a vertical circulation of water, but in the lower colder hypolimnion no circulation takes place. The region of transition between the two is quite sharp, and cases have been reported by Birge and Juday ('11) of a drop of 5 to 8 degrees Centigrade in a depth of two meters at the point of the thermocline. Investigations by Goodnough ('05) on Jamaica Pond at the time of thermal stratification have shown that two days after an application of copper sulphate at the rate of 1/2,000,000, the copper sulphate content of the epilimnion was several times that of the hypolimnion. If, therefore, the lake to be treated has a marked thermal stratification the computation of the volume of water to be treated should include only the epilimnion and thermocline and not the hypolimnion.

Fig. 18. Pumping samples of the plankton from Carr Pond, Palisades Interstate Park.

Another prime requisite before treating a lake is a knowledge of the specific organism or organisms causing the disturbance. (Figure 18 illustrates a method of securing samples of plankton.) This is essential because different algae vary greatly in their ability to withstand the toxic effects of copper sulphate; the susceptibility ranging from *Uroglena* which is killed by one part of copper sulphate in 20,000,000 of water, to *Scenedesmus* and *Kirchneriella* which require application of five parts per million for their eradication. The compilation of a table showing the copper sulphate requirements for destroying the various organisms represents only an approximation, since the varying factors mentioned above increase or decrease the toxic limits for any particular alga. Tables based upon actual field practice have been compiled by Moore and Kellerman and by Jackson and Kellerman. These, as well as reports on the toxicity point in the individual treatment of lakes, have been used in compiling the following table. The most recent series of experiments, those of Huff ('16), seem to show that even greater dilutions of copper sulphate will give the desired results, although attention should be called to the fact that he assumes an even distribution of the algicide when studying a lake with a marked thermal stratification.

The only method of determining the organisms causing the trouble is a microscopical examination of the "bloom," and it is hoped that the illustrations accompanying this report (Plates 3–24) will be of service in determining such algae. Experience has shown that different species of the same genus may react differently to the copper sulphate, and whenever possible specific determination should be made. Many of the genera incorporated in the following table are not of immediate concern in the problem of blooming at the Palisades Park, but the reaction of all algae which have been treated with copper sulphate is given for the sake of completeness.

TABLE 3.— *Showing the observed effect of various concentrations of copper sulphate on different algae.*

Kind of Algae	Parts $CuSO_4$ per million of water	Effect	References
BACILLARIEAE			
Asterionella sp.	1.00	Greatly reduced	Carroll ('04)
Asterionella sp.	1.00	Killed	Caird ('04)
Asterionella sp.	.30	Killed	Jackson ('05a, '05b)
Asterionella sp.	.12	Killed	Moore and Kellerman ('05)
Asterionella sp.	.10	Killed	Kellerman ('12)
A. formosa	.10	Killed	Huff ('16)
A. formosa	.08	Greatly reduced	Huff ('16)
Cyclotella comta	.08	Killed	Huff ('16)
Fragilaria sp.	1.25	Killed	Jour. N. E. W. W. Assn. Table ('05)
Fragilaria sp.	.25	Killed	Jackson ('05a, '05b); Kellerman ('12); Moore and Kellerman ('05)
F. capunica	.10	Killed	Huff ('16)
F. capunica	.08	Greatly reduced	Huff ('16)
Melosira sp.	.30	Killed	Jackson ('05a, '05b)
M. granulata	.10	Killed	Huff ('16)
M. granulata	.08	Greatly reduced	Huff ('16)
Navicula sp.	.50	Killed	Jour. N. E. W. W. Assn. Table ('05)
Navicula sp.	.07	Killed	Moore and Kellerman ('05)
N. gracilis	.22	Not affected	Quick ('04)
Stephanodiscus sp.	4.00	Killed	Moore and Kellerman ('05)
S. niagarae	.10	Killed	Huff ('16)
Synedra sp.	1.66	Killed	Moore and Kellerman ('05)
Synedra sp.	1.00	Killed	Jackson ('05a)
Synedra sp.	.30	Killed	Jackson ('05b)
S. pulchella	.10	Killed	Huff ('16)
S. pulchella	.08	Greatly reduced	Huff ('16)
Tabellaria sp.	1.66	Killed	Moore and Kellerman ('05)
Tabellaria sp.	.20	Greatly reduced	Jour. N. E. W. W. Assn. Table ('05)
MYXOPHYCEAE			
Anabaena sp.	1.00	Killed	Jour. N. E. W. W. Assn. Table ('05)
Anabaena sp.	.50	Killed	Jour. N. E. W. W. Assn. Table ('05); Caird ('05)
Anabaena sp.	.33	Killed	Jour. N. E. W. W. Assn. Table ('05)
Anabaena sp.	.30	Killed	Caird ('05, '04)
Anabaena sp.	.25	Killed	Jour. N. E. W. W. Assn. Table ('05)
Anabaena sp.	.12	Killed	Jour. N. E. W. W. Assn. Table ('05); Goodnough ('05); Jackson ('05a, '05b)
Anabaena sp.	.09	Killed	Kellerman ('12)
A. circinalis	1.00	Killed	Carroll ('04)
A. circinalis	.10	Killed	Moore and Kellerman ('05)
A. flos-aquae	.10	Killed	Moore and Kellerman ('05); Huff ('16)
A. flos-aquae	.08	Greatly reduced	Huff ('16)
Aphanizomenon sp.	.50	Killed	Jour. N. E. W. W. Assn. Table ('05)
Aphanizomenon sp.	.25	Killed	Jour. N. E. W. W. Assn. Table ('05)
Aphanizomenon sp.	.20	Killed	Moore and Kellerman ('05)
Aphanizomenon sp.	.12	Killed	Jackson ('05a, '05b)
A. flos-aquae	.10	Killed	Huff ('16)
A. flos-aquae	.08	Greatly reduced	Huff ('16)
Clathrocystis sp.	.50	Killed	Jour. N. E. W. W. Assn. Table ('05)
Clathrocystis sp.	.25	Killed	Jackson ('05b)
Clathrocystis sp.	.12	Killed	Moore and Kellerman ('05); Jackson ('05a)
Clathrocystis sp.	.10	Killed	Kellerman ('12)
C. aeruginosa	.10	Killed	Huff ('16)
C. aeruginosa	.08	Greatly reduced	Huff ('12)
Oscillatoria sp.	.50	Killed	Jour. N. E. W. W. Assn. Table ('05)
Oscillatoria sp.	.30	Killed	Jackson ('05a); Jour. N. E. W. W. Assn. Table ('05)
Oscillatoria sp.	.20	Killed	Jackson ('05b)
Oscillatoria sp.	.10–.40	Killed	Kellerman ('12)
O. prolifica	.70	Killed	Goodnough ('05)
O. prolifica	.50	Not affected	Jour. N. E. W. W. Assn. Table ('05)
O. prolifica	.20	Not affected	Jour. N. E. W. W. Assn. Table ('05)
Coelosphaerium sp.	.30	Killed	Moore and Kellerman ('05); Kellerman ('12)
Coelosphaerium sp.	.25	Killed	Jackson ('05a, '05b)
C. Kuetzingianum	.10	Killed	Huff ('16)
C. Kuetzingianum	.08	Greatly reduced	Huff ('16)
Rivularia echinulata	.10	Killed	Huff ('16)
Rivularia echinulata	.08	Greatly reduced	Huff ('16)

TABLE 3.— *Concluded.*

Kind of Algae	Parts $CuSO_4$ per million of water	Effect	References
CHLOROPHYCEAE			
Ankistrodesmus sp	3.00	Killed	Moore and Kellerman ('05)
Ankistrodesmus sp	.30	Killed	Jackson ('05a, '05b)
Botryococcus sp	.22	Killed	Quick ('04)
Chara sp	1.00	Greatly reduced	Jour. N. E. W. W. Assn. Table ('05)
Chara sp	.50	Killed	Jour. N. E. W. W. Assn. Table ('05)
Chara sp	.30	Killed	Emberley ('12)
Chara sp	.12	Not affected	Jour. N. E. W. W. Assn. Table ('05)
Chlamydomonas sp	1.00	Killed	Moore and Kellerman ('05); Jour. N. E. W. W. Assn. Table ('05)
Chlamydomonas sp	.50	Killed	Jackson ('05a, '05b)
Chlamydomonas sp	.20	Greatly reduced	Jour. N. E. W. W. Assn. Table ('05)
Cladophora sp	1.00	Killed	Moore and Kellerman ('05); Kellerman ('12)
Closterium sp	.30	Killed	Jackson ('05a, '05b); Caird ('05)
Closterium sp	.16	Killed	Moore and Kellerman ('05)
Conferva sp	2.00–.40	Killed	Kellerman ('12)
Conferva sp	.30	Killed	Jackson ('05a, '05b)
Conferva sp	.20	Killed	Jour. N. E. W. W. Assn. Table ('05)
C. bombycina	.30	Killed	Moore and Kellerman ('05)
Desmidium sp	2.00	Killed	Moore and Kellerman ('05)
Draparnaldia sp	.30	Killed	Moore and Kellerman ('05); Jackson ('05a, '05b)
Eudorina elegans	10.00	Killed	Moore and Kellerman ('05)
Eudorina elegans	.10	Greatly reduced	Huff ('16)
Hydrodictyon sp	.20	Killed	Jour. N. E. W. W. Assn. Table ('05)
Hydrodictyon sp	.10	Killed	Moore and Kellerman ('05); Jackson ('05a, '05b); Kellerman ('12)
Kirchneriella sp	10.–5.00	Killed	Kellerman ('12)
Microspora sp	.40	Killed	Kellerman ('12)
Palmella sp	2.00	Killed	Moore and Kellerman ('05)
Pandorina morum	10.00	Killed	Moore and Kellerman ('05)
Pandorina morum	.10	Greatly reduced	Huff ('16)
Protococcus sp	1.40	Killed	Goodnough ('05)
Protococcus sp	.30	Killed	Jour. N. E. W. W. Assn. Table ('05); Caird ('05)
Protococcus sp	.22	Not affected	Quick ('04)
Scenedesmus sp	10.–5.00	Killed	Kellerman ('12)
Scenedesmus sp	1.40	Killed	Goodnough ('05)
Scenedesmus sp	1.00	Killed	Moore and Kellerman ('05)
Scenedesmus sp	.70	Greatly reduced	Goodnough ('05)
Scenedesmus sp	.30	Killed	Jackson ('05a, '05b)
Spirogyra sp	.20	Killed	Jour. N. E. W. W. Assn. Table ('05); Jackson ('05a, '05b)
Spirogyra sp	.12	Killed	Jour. N. E. W. W. Assn. Table ('05)
Spirogyra sp	.05–.20	Killed	Kellerman ('12)
Spriogyra sp	.04	Killed	Moore and Kellerman ('05)
Staurastrum sp	1.40	Killed	Goodnough ('05)
Staurastrum sp	.27	Not affected	Goodnough ('05)
Staurastrum sp	.10	Killed	Huff ('16)
Ulothrix sp	.50	Killed	Caird ('05)
Ulothrix sp	.20	Killed	Moore and Kellerman ('05); Kellerman ('12)
Ulothrix sp	.16	Killed	Quick ('04)
Volvox sp	.25	Killed	Moore and Kellerman ('05); Jackson ('05a, '05b); Kellerman ('12)
Zygnema sp	.70	Killed	Kellerman ('12)
Zygnema sp	.50	Killed	Moore and Kellerman ('05)
PHAEOPHYCEAE			
Dinobryon sp	.30	Killed	Jackson ('05a)
D. setularia	.08	Killed	Huff ('16)
Glenodinium sp	.50	Killed	Moore and Kellerman ('05); Jackson ('05a, '05b)
Mallomonas sp	2.00	Killed	Moore and Kellerman ('05)
Mallomonas sp	.50	Killed	Jackson ('05a, '05b)
Peridinium sp	2.00	Killed	Moore and Kellerman ('05); Kellerman ('12)
Peridinium sp	.50	Killed	Jackson ('05a, '05b)
Synura sp	.30	Killed	Moore and Kellerman ('05)
Synura sp	.10	Killed	Jackson ('05a, '05b)
Uroglena sp	.25	Killed	Jour. N. E. W. W. Assn. Table ('05)
Uroglena sp	.08	Killed	Goodnough ('05); Huff ('12)
Uroglena sp	.05	Killed	Jour. N. E. W. W. Assn. Table ('05); Moore and Kellerman ('05); Jackson ('05a, '05b)
Uroglena sp	.04	Not affected	Goodnough ('05)

At present it is impossible to state the mechanism by which extremely toxic substances like copper sulphate produce marked results, even when greatly diluted. There are, however, certain factors governing this chemical reaction that are of importance, and that were first pointed out by Moore and Kellerman ('04). They call attention to the fact that the relation between temperature and chemical reaction, so well known in chemical reactions, holds in the toxic effect of copper sulphate, and that smaller amounts will produce the same results when applied during the period when the water is at a midsummer temperature. Their computations of the amount needed to kill the algae are based upon a standard temperature of 15° C. (59° F.) and they recommend an increase or decrease of 2.5 per cent in the amount of copper sulphate for each degree Centigrade below or above the standard temperature.

The chemical constitution of the water, both organic content and temporary hardness, affects the reaction, and copper sulphate proves less toxic in hard waters and in those rich in organic matter. Moore and Kellerman ('05) suggest a 2 per cent increase in the amount of copper sulphate for each ten parts per million of organic matter, and a .5 per cent increase for each ten parts per million of temporary hardness.

The question of introducing a poisonous substance like copper sulphate into drinking water at once aroused interest in the problem of the chemical reactions of this substance with surface waters; and especially in the question of whether it remains in solution or is precipitated out. Experience has shown that in ordinary or hard waters the copper sulphate is precipitated out within a few days, while in soft waters it may remain for some time. Ellms ('05) has suggested the following reaction to account for the precipitation of the compound from natural waters:

$$2\,CuSO_4 + 2CaH_2(CO_3)_2 = CuCO_3.CuO_2H_2 + 2\,CaSO_4 + 3\,CO_2 + H_2O$$

Calcium Bicarbonate — Basic copper Carbonate

The basic copper carbonate formed is soluble to a certain extent, especially if there is carbon dioxid in the water. Carbon dioxid is generally present as a result of respiration of organisms in the water, or there may be a small amount produced by the reaction suggested above. Following the formation of the basic copper carbonate there is a change to copper hydrate, an insoluble compound, which is then precipitated to the bottom of the lake:

$$CuCO_3.CuO_2H_2 + H_2O = 2\,CuO_2H_2 + CO_2$$

In the hard waters with which Ellms worked 70–95 per cent of the basic copper carbonate was converted into copper hydrate by the end of three hours, and at the end of twenty-four hours no trace of copper compounds remained in solution. He also noted that this second reaction was affected by the organic content of the water, and when caramel solution or a leaf extract was added the reaction was much slower.

The Method of Applying Copper Sulphate. After determining the amount of copper sulphate needed and making the proper adjustments for temperature, chemical nature of the water, and the other factors mentioned above, the problem of the method of placing the copper sulphate in the water arises. The best method is that first devised by Moore and Kellerman (see figure 19) whose instructions follow:

"The method of introducing the copper sulphate into a water supply is extremely simple. Place the required number of pounds of copper sulphate in a coarse bag — gunny sack or some equally loose mesh — and, attaching this to the stern of a rowboat near the surface of the water, row slowly back and forth over the reservoir, on each trip keeping the boat within 10 to 20 feet of the previous path. In this manner about 100 pounds of copper sulphate can be distributed in one hour. By increasing the number of boats, and, in the case of very deep reservoirs, hanging two or three bags to each boat, the treatment of even a large reservoir may be accomplished in from four to six hours. It is necessary, of course, to reduce as much as possible the time required for applying the copper, so that for immense supplies with a capacity of several billion gallons it would probably be desirable to use a launch, carrying long projecting spars to which could be attached bags each containing several hundred pounds of copper sulphate."

The application should be made, if possible, at a time when the wind is blowing and the water in circulation, in order to secure an even distribution of the copper sulphate. There are usually shallow places in a lake where it is impossible to row a boat or where, if a boat can be pushed through, the disturbance of the muddy bottom may cause a too rapid precipitation of the copper. Huff ('16) has found a small hand pump, the type used for spraying trees, very useful in distributing a strong copper sulphate solution in these inaccesible places which frequently form breeding centers for the algae. This gives a much more uniform distribution in these inaccessible places than sowing broadcast finely powered copper sulphate.

The number of applications necessary for eradication of algae depends upon varying conditions. If the algae in a body of water have been killed off the inference might be drawn that the trouble has been eliminated for all time, but experience has shown that the same algae or other algae sometimes reappear in large numbers in the same season. The explanation for this rests upon the rapid multiplication of these organisms, the increase in the number of individuals being a geometric and not an arithmetic progression. From the theoretical standpoint a single cell left in a lake could produce a bloom within 30 to 40 days if conditions for its reproduction were not limited by certain factors. In practice it has been found that after the eradication of the algae it is generally a month before they again become troublesome and that three treatments during a season are sufficient to hold the algae in check. The fear expressed by some

Fig. 19. Applying copper sulphate treatment to Carr Pond. The copper sulphate is suspended in loose-meshed bags at the rear of the rowboats.

that the algae surviving the treatment would develop a strain resistant to copper sulphate in small quantities has not been realized, and algae yield to treatment in reservoirs where the method of eradication has been practiced since it was discovered twenty years ago.

EFFECT OF THE COPPER SULPHATE TREATMENT ON FISH

The plan for the recreational and educational development of the Palisades Interstate Park includes the cultivation of fish in its ponds and lakes, in order to increase their utility and the recreational possibilities of the Park. A preliminary report on a general fish cultural policy for the Park has been published (Adams, Hankinson and Kendall, '19) based on field studies during the summers of 1918 and 1919.

The superabundance of algae, particularly in ponds abounding in decaying plant remains (as in Carr Pond) has been given as the cause for the death of fish. Among the records of the sudden dying of fish where it is ascribed to algae are the observations of Haine ('18), Hyams and Richards ('01), Baldwin and Whipple ('06) and an anonymous report in the Bulletin of the New York Zoological Society ('13). The investigations of Baldwin and Whipple were the most complete and they show that while the algae killed the fish they did not poison them directly, but that the death of the algae following their blooming caused an exhaustion of the oxygen supply, which, in turn, caused the death of the fish. That this death of fish in connection with a blooming of the pond is due to the exhaustion of the oxygen is borne out by the observations of Haine ('18), who shows that when algae have been killed by copper sulphate there is a sharp decrease in the oxygen content of the water following such treatment, due to the bacterial oxidation of the dead algae, and that this oxygen reduction may affect the fish.

The question of the effect of copper sulphate upon fish as well as upon algae is of great importance. This question was raised soon after the introduction of Moore and Kellerman's method, especially in its application to aquaria and fish cultural waters. A more recent use of copper sulphate is in the application of it in sufficient quantities to kill undesirable fish before restocking with certain game fish (Titcomb, '14). When these different points of view are taken into consideration we have a greater knowledge of the reaction to this compound than might be expected, although attention should be called to the fact that any particular species of fish shows a greater range of susceptibility in different sections of the country than do the algae. This may be due to the fact that there are physiological differences between species of fish in different localities, even when fish from different localities appear to be identical. This indicates that local investigations must be made the basis of practical remedial work. Fortunately fish are less susceptible than algae and, although the toxic limits of the two frequently approach, it is often possible to eradicate algae without seriously harming the fish. The following table shows the reported responses of fish to different concentrations of copper sulphate.

TABLE 4.—*Showing the observed effects of copper sulphate on fish. (Amount of copper sulphate expressed in parts per million.)*

Kind of Fish	Concentration of $CuSO_4$	Effect	References
Bass	.60	Killed	Jour. N. E. W. W. Assn. ('05). (Moore, Jackson, Goodnough '05)
Black bass (small)	.30	Killed	Caird ('04)
Black bass (small)	2.10	None killed	Kellerman ('12)
Large-mouth black bass	10.00	Killed	Marsh and Robinson ('10)
Large-mouth black bass	5.00	None killed	Marsh and Robinson ('10)
Carp	.30	None killed	Kellerman ('12)
Catfish	.34	Killed	Jour. N. E. W. W. Assn. ('05)
Catfish	.40	None killed	Kellerman ('12)
Goldfish	.50	None killed	Kellerman ('12)
Perch	.60	Killed	Jour. N. E. W. W. Assn. ('05)
Perch	.75	None killed	Kellerman ('12)
Perch	1.42	Few killed	Goodnough ('05)
Perch (yellow)	12.00	Killed	Titcomb ('12)
Perch (yellow)	.30	None killed	Marsh and Robinson ('10)
Perch (yellow)	.40	Killed	Marsh and Robinson ('10)
Perch (yellow)	.50	None killed	Marsh and Robinson ('10)
Perch (yellow)	.50	Killed	Marsh and Robinson ('10)
Perch (yellow)	1.00	Killed	Marsh and Robinson ('10)
Pickerel	.12	Few killed	Jour. N. E. W. W. Assn. ('05)
Pickerel	.40	None killed	Kellerman ('12)
Pickerel	12.00	Killed	Titcomb ('14)
Pickerel	30.00	Killed	Titcomb ('14)
Pike	30.00	Killed	Titcomb ('14)
Pike perch	12.00	Killed	Titcomb ('14)
Suckers	.30	None killed	Kellerman ('12)
Suckers	.60	Killed	Jour. N. E. W. W. Assn. ('05)
Sunfish	.30	Killed	Jour. N. E. W. W. Assn. ('05)
Sunfish	.60	Killed	Caird ('04)
Sunfish	1.20	None killed	Kellerman ('12)
Trout	.14	None killed	Kellerman ('12)
Trout	1.00	None killed	Anonymous ('04)
Trout (fry)	2.00	None killed	Marsh and Robinson ('10)
Trout (brook)	.30	None killed	Marsh and Robinson ('10)
Trout (brook)	.60–.80	None killed	Marsh and Robinson ('10)
Trout (brook) (fry)	1.00	None killed	Marsh and Robinson ('10)
Trout (brook) (fry)	2.00	Killed	Marsh and Robinson ('10)
Trout (brown)	.60–.80	None killed	Marsh and Robinson ('10)
Trout (rainbow)	.60–.80	None killed	Marsh and Robinson ('10)
Trout (rainbow)	.30	None killed	Marsh and Robinson ('10)

When there is any doubt concerning the toxic effect of copper sulphate the method of Marsh and Robinson ('08) may be used. The U. S. Bureau of Fisheries gives the following directions:

" Each body of water must be treated in the light of its special conditions. It is advisable to conduct a preliminary experiment on the effect of various dilutions of the copper sulphate upon the fish in the water to be treated. For this purpose two vessels of sufficient size to hold a few of the fish for 24 hours without artificial aeration are placed side by side. Both of the vessels should be filled with water of the same temperature as that of the water from which the fish are taken. To the water in one of the vessels add sufficient copper sulphate to make a solution containing 1 part of the salt to a million parts of water. The copper sulphate is conveniently added to the water in the form of an aqueous solution of known strength (standard solution) which may be made up in the following manner: Weigh out 20 grains of crystalline copper sulphate. (If facilities for weighing are lacking, the chemical may be weighed at a drug store). Completely dissolve this amount of salt in one quart of water. Of this standard solution add one fluid ounce to every 10 gallons of water, which are contained in the treating vessel. After stirring the solutions vigorously to aerate the water, place an equal number of fish in each of the two vessels, one of which now contains 1 part of copper sulphate to one million parts of water and the other contains untreated water. If the fish die in less than 24 hours in the copper sulphate solution and not in the control, it is evidence that the chemical solution was too strong and a second trial should be made, using a fractional part of an ounce of the standard copper sulphate solution to 10 gallons of water (the resultant solution would of course contain a corresponding fraction of a part per million of copper sulphate). If the fish in the experimental solution, however, did not die, then this strength of copper sulphate solution can be used for the eradication of the algae without killing the fish."

In July, 1918, in Carr Pond in the Palisades Interstate Park, the algae became so abundant and were such a nuisance that an effort was made to adopt control measures. The Park Commissioners therefore sought permission of Mr. Geo. D. Pratt, State Conservation Commissioner, Albany, to use the copper sulphate method for killing the algae, to which he replied on July 19: "You are authorized to use in Carr Pond commercial copper sulphate, ratio one part dry weight of copper sulphate to 5 millions parts of water. Rag bags filled as above so that applications be distributed uniformly."

Under this authorization five park workmen, under my direction on July 22, 1918, made the treatment (figure 19). The estimate of the volume of the lake was furnished by the office of the Chief Engineer of the Park. Since the organism causing the bloom was *Anabaena* the maximum concentration permitted was not used for its eradication. Soon after the application of the copper sulphate the color of the water turned from a grass-green to a lighter bluish shade, because of the killing of the algae. After the copper sulphate had been in the lake for 24 hours many fish were seen at the surface gasping for air. A small species of catfish (*Schilbeodes*) was killed in large numbers, while the pickerel (*Esox tridecimlineatus*) was very sluggish and swimming slowly at the surface. The following day many pickerel were dead as well as some of the large perch. The large sunfish (*Eupomotis gibbosus*) was not affected. Collections of plankton samples at this time showed that the *Anabaena* had disappeared although the water still remained somewhat turbid. The third day fish were not noted at the surface.

This treatment of the lake brings out the fact that although the amount of copper sulphate used was considerably below the toxic limits for the fish the biological conditions following the treatment were so unfavorable that the fish died. The oxygen content of the water generally drops following the killing of the algae, and in this case the reduction was, for a short time, below a point at which the fish could exist. Haine ('18) ascribes this oxygen reduction to the bacterial oxidation of the dead algae and calls attention to the same reduction in the amount of oxygen when algae in a body of water are suddenly killed by some natural cause. The best known case of the killing of fish by the sudden dying of algae is that reported by Baldwin and Whipple ('06).

These injurious after effects may be avoided by eradicating the algae at the first indication of their development in quantity by several treatments, instead of at the time of their maximal development; in such cases the bacterial decomposition of the algae will not require so much oxygen. If the treatment is made at a time when the waters are not well aerated by the action of waves only a portion of the lake should be treated at a time. Under this method there are regions into which the fish may migrate and not be affected by the reduction of the oxygen.

In conclusion it should be pointed out that the killing of the algae destroys an important source of food for fish. In general, algae are not directly a source of food for many species of fish, although Tiffany ('21a, 21b, '22) has shown that the young gizzard shad (*Dorsoma cepedianum*) feed almost exclusively upon algae. Algae are, however, the food of the aquatic animals upon which many fish feed, and the complete removal involves the removal of their food supply also (Transeau, '17; Moore, '20; Mann, '21). It is very evident that the whole problem of the relation of algae to fish and fish culture is in great need of further detailed investigation.

SYSTEMATIC ACCOUNT OF THE PHYTOPLANKTON OF PALISADES PARK

In the following list, and in the table of the phytoplankton of the Park (pp. 140-145) the frequency of occurrence in different lakes is designated as follows: (cc) common, (c) fairly common, (s) fairly scarce, (ss) scarce, (sss) very scarce, (r) fairly rare, (rr) rare, (rrr) very rare. Since determination of the plankton algae is aided more by figures than by descriptions special attention has been given to the illustration of the plankton algae of the Park (Plates 3–24). New or noteworthy species are as follows:

Coelosphaerium radiatum sp. nov. Pl. 3, Figs. 9-10.

Colonies containing comparatively few cells, enclosed by a very hyaline, homogeneous, gelatinous envelope. Cells ovoid-pyriform, radially arranged about a common center and with their smaller ends facing outwards. Cells lying some distance from one another. Cell contents homogeneous, pale blue-green in color.

Cells 5–6 μ long, 1.75–2.0 μ broad; diam. of colonies 16–19 μ.

Popolopen Pond (rr).

This species is characterized by the peculiar cell shape, the small number of cells in the colony, and by the arrangement of the cells within the colony.

Synura Adamsii sp. nov. Pl. 5, Figs. 4–5.

Colonies usually spherical, with the cells loosely arranged to form a radiating mass from a common center. Cells elongate club-shaped, with the proximal ends subacute and the anterior portion of the cell with a few scattered spines. Cells with two elongate, laminate chromatophores and two cilia of equal length.

Length of cells 42–47 μ, breadth 6.5–10 μ, length of cilia 12–17 μ.

Little Dam Pond (rr), Little Long Pond (r).

The ratio between breadth and length of the cell in this species is 1:4 to 1:6 whereas in the common *S. uvella* it is 1:2 to 1:3.5. The spines on the cell wall do not cover more than the anterior quarter of the cell in this species.

The behavior of the two species when mounted under a cover glass is also quite different since colonies of *S. Adamsii* begin to dissociate into individual cells almost as soon as they are mounted. Colonies of *S. uvella,* on the other hand, do not break down readily.

Errerella bornhemiensis Conrad. Pl. 9, Figs. 3–4.
Bull. Soc. Roy. de Bot. de Belgique 52: 242, text figs. 1-3. 1913.
Nigger Pond (rr), Portage Lake (rrr).

This remarkable alga has not been noted since its discovery by Conrad. It is very closely related to *Micractinium* but differs in the cellular arrangement and the single long spine on certain of the exterior cells.

Conrad states that the colony consists of a solid pyramid of sixteen cells. In the specimens that I have observed the unit of structure is in reality a pyramid of four cells which, in turn, is grouped with three other units to form a pyramid of sixteen cells. In this sixteen-celled pyramid there is an open space at the center. Isolated sixteen-celled colonies were found but in the majority of cases development had extended to a point where four such sixteen-celled colonies were joined to form a pyramid that contained sixty-four cells. In one case four of these sixty-four-celled colonies were joined to form a pyramidal colony of 256 cells. This colony has been drawn in basal view to show the pyramidal arrangement to better advantage (Fig. 3).

The cells of the New York specimens are somewhat smaller than Conrad describes, the diameter varying from 3–6 μ. The chloroplast is cup-shaped, but the hyaline portion of the protoplast is opposite and not away from the single spine. As in the Belgian specimens those from New York have no pyrenoids, but this presence or absence of pyrenoids is a matter of minor importance.

Conrad was unable to find stages of reproduction and so suggests that reproduction may either be by zoospores as in *Pediastrum* or by autocolonies. Small pyramidal colonies of four cells still enclosed by the old cell wall were observed in the plankton of Nigger Lake. This gives every reason for supposing, therefore, that reproduction is by autocolonies as in the closely related *Micractinium.*

Pachycladon gen. nov.

Cells solitary, spherical, with a delicate cell wall that is without a gelatinous envelope. Cell wall bearing four quadrately (very rarely pyramidately) arranged appendages. Appendages dark brown in color, stout, gradually tapering to a blunt point that is usually bifurcate. Base of appendages dilate at point of juncture with the cell wall. Chloroplast single, cup-shaped, parietal, nearly filling the cell cavity; with one pyrenoid.

Reproduction unknown.

Pachycladon umbrinus sp. nov. Pl. 9, Figs. 5–7.

Characters as above.

Diameter of cells without processes 8.5–12.5 μ, with processes 84–112 μ. Length of processes 35–50 μ; breadth of processes at base 2.5–3.75 μ, at apex 1.0–2.0 μ.

Little Dam Pond (rr), Nigger Pond (rr).

This genus belongs in the subfamily of the *Micractinieae* and is separated from the other members of the group by the stout appendages that do not terminate in a sharp point as well as by the solitary spherical cells. The basal portion of the appendages shows a certain similarity with those of *Lagerheimia wratislawiensis* Schröd., but the apices and the stoutness of the processes are quite different. There is also a superficial resemblance between *P. umbrinus* and *Cerasterias longispina* (Perty) Reinsch but in the latter species the long processes are a continuation of the cell wall and not distinct appendages.

Schroderia setigera (Schröd.) Lemm. Pl. 10, Figs. 3–5.

In the discussion of the Wisconsin species of this genus attention was called to a fine disc at the end of one of the terminal spines. This was thought to be a character of all species of the genus but I am now convinced that both the *S. setigera* and *S. Judayi* described from Wisconsin lakes should be referred to a single species, *S. Judayi* G. M. Smith. The reason for this view is the discovery in Stahahe Lake of an organism that agrees well with the original description of *S. setigera* which states that there are simple spines at both poles of the cell. The chloroplast of the New York specimens usually had but a single pyrenoid, although some specimens were observed which contained more than one pyrenoid (Fig. 5).

Pediastrum biradiatum var. **heterocanthum** var. nov. Pl. 12, Fig. 14.

Incisions in apices of lobes of marginal cells unequal, the interior lobelets being much larger than the exterior.

Cells 8 μ broad, 14 μ long; diam. of sixteen-celled 55 μ.

Nigger Pond (rrr).

The shape of the marginal cells suggests very strongly *P. tetras* var. *tetraodon* (Corda) Hansg. but the interstices between the interior cells and the lateral contact of marginal cells at the bases only show that the alga should be referred to *P. biradiatum* Meyen.

Micrasterias mahabuleshwarensis var. **serrulata** (Wolle) comb. nov. Pl. 16, Fig. 2.

Micrasterias ringens var. *serrulata* Wolle, Bull. Torr. Bot. Cl. 12: 128, pl. 51, fig. 15. 1885.

This species is subject to considerable variation. The majority of the individuals in Little Long Pond lacked the accessory processes on the top of the polar lobe. With the exception of this feature the variety agrees well with the type in shape and ornamentation of the lateral lobes, central protuberance of the semicells, and shape of the polar lobe. This variety may be considered identical with an organism that Wolle describes as *M. ringens* var. *serrulata* but which seems in a more natural place when considered a variety of *M. mahabuleshwarensis*.

Xanthidium subhastiferum var. **Johnsonii** (W. & G. S. West) comb. nov. Pl. 16, Figs. 6–7.

Xanthidium hastiferum var. *Johnsonii* W. & G. S. West. Jour. Linn. Soc. Bot. 33: 299. 1898.

Xanthidium antilopaeum var. *javanicum* Johns. non. Nordst. Bull. Torr. Bot. Cl. 22: 295, pl. 239, fig. 10. 1895.

Semicells broadly elliptic, with an arcuate row of pores just below the apex. Lateral margins of semicells with two robust, upwardly curved spines.

Length 45–48 μ; breadth without spines 43–47 μ, with spines 65–75 μ; length spines 12–15 μ; breadth at isthmus 9–12 μ.

This alga suggests very strongly the one which Johnson referred to *X. antilopaeum* var. *javanicum* Nordst. The two stout spines at the lateral angles of the semicells show that it belongs to the *X. hastiferum-subhastiferum-controversum* group of species that have two pairs of spines on the lateral margins. The cell shape is that of *X. subhastiferum* but it differs in the curved spines and the subapical ornamentation.

Staurastrum trihastiferum sp. nov. Pl. 17, Figs. 5–6.

Cells very large, breadth (without spines) 1.5–1.75 times the length, deeply constricted, sinus widely open and with an acute apex, isthmus narrow. Semicells obversely semicircular, apices markedly tumid, lateral angles rounded and bearing a single long, stout, solid spine. Spines subparallel and generally slightly outwardly divergent at their apices. Vertical view triangular, sides somewhat retuse in the central portion, angles fairly sharp and bearing a single stout spine. Cell wall coarsely punctate.

Zygospores unknown.

Length 90 μ; breadth without spines 77–93 μ, with spines 115–138 μ; length spines 22.5–30 μ; breadth of isthmus 24 μ.

This desmid is separated from other species bearing single spines at the corners of the semicells by its large size. It should be compared with *S. minnesotense* Wolle and *S. longispinum* var. *bidentatum* (Wittr.) W. & G. S. West, which differ in having two large spines at the angles of the semicells.

Staurastrum chaetoceras (Schröd.) comb. nov. Pl. 18, Fig. 3.

Staurastrum polymorphum var. *chaetoceras* Schröder in Zacharias, Forschungsbr. a. d. Biol. Stat. zu Plön 6: 131, text figs. a–c. 1898.

An alga which is worthy of specific rather than varietal rank.

Staurastrum Johnsonii var. **triradiatum** var. nov. Pl. 18, Figs. 5–7.

Vertical view triangular; ornamentation of the front view as in the biradiate type.

Length without processes 32–42 μ, with processes 50–64 μ; breadth with processes 55–75 μ; breadth isthmus 8.5–11.5 μ.

This variety resembles *S. cingulum* (W. & G. S. West) G. M. Smith, in the general cell shape and transverse row of granules just above the isthmus; but the ornamentation of the apices of the semicells, the verrucae and the subapical rings of minute verrucae, is that of *S. Johnsonii.*

Staurastrum pseudopelagicum var. **minor** var. nov. Pl. 18, Figs. 13–14.

Length without processes 16.5–22.5 μ, with processes 30–38 μ; breadth with processes 42–50 μ; breadth isthmus 6–7 μ.

TABLE 5.—SHOWING THE DISTRIBUTION OF THE PLANKTON ALGAE IN THE LAKES OF PALISADES PARK

	Plate	Figure	Barnes	Cedar	Cranberry	Cromwell	Echo	Forest	Green	Highland	Island	Kanahwauke (Upper)	Kanahwauke (Lower)	Little Dam	Little Long	Long	Mine	Mombasha	r g	Popolopen	Portage	Queensboro	Rockland	Shepard	Stahahe	Smmmit	Twin (Upper)	Twin (Lower)
	p.	f.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
CLASS MYXOPHYCEAE																												
Order Coccogoneales																												
Chroococcus limneticus Lemm.	3	1	...	rrr	...	rrr	...	rrr	r	...	rrr	...	...	...	ss	...	...	rr	...	...	rr	...	...	...	...	sss	rr	rrr
Chroococcus minutus (Ktz.) Naeg.	3	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	r	...	...
Chroococcus turgidus (Ktz.) Naeg.	3	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	rrr	...	...	...	...	...
Merismopedia elegans A. Br.	3	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	rrr	...	...	...	...	...
Merismopedia tenuissima Lemm.	3	5–6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	rrr	...
Coelosphaerium Kuetzingianum Naeg.	3	**7**	**rrr**	rrr	rr	rrr	...	...	...	...	...	...	...	...	rrr	...	...	rr	...	...	...	...	rr	...	...	...	...	rrr
Coelosphaerium Naegelianum Ung.	3	**8**	sss	ccc	ss	...	...	rrr	...	...	...	...	...	...	rrr	...	rrr	...	ss	ss	rrr	...	...	...	...	rrr	...	rrr
Coelosphaerium radiatum sp. nov.	3	9–10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	...	...	...	...	...	...	...
Microcystis flos-aquae (Wittr.) Kirchn.	3	11	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	rr	...	...	...	rr	...	...	...	...	rrr
Microcystis aeruginosa Ktz.	3	12	...	...	r	r	rr	...	...	...	rrr	...	...	...	...	...	...	...	sss	rr	...	...	sss	...	rr	...	...	...
Microcystis pulvera (Wood) Migula	3	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	ss	...	...	...	...	...
Aphanocapsa elachista var. *planctonica* W. & G. S. West	4	1	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	...	...	...	...	...	...	...	...	...	rr	...	...
Aphanothece nidulans P. Richt.	4	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	sss	...	...
Order Hormogoneales																												
Trichodesmium lacustre Klebh.	4	3	...	...	rr	...	...	...	...	...	...	...	...	...	rr	...	...	...	...	...	...	...	...	...	...	...	r	rr
Anabaena Bornetiana Collins	4	4	...	...	...	rr	...	...	...	...	...	...	...	...	...	...	...	sss	...	...	...	...	...	...	aaa	...	rr	...
Anabaena flos-aquae (Lyng.) Bréb.	4	5	...	...	rr	...	...	rr	...	...	...	rr	r	...	...	ccc	...	...	...	...	rr	...	...	...	rrr	...	rr	rr
Anabaena Lemmermanni P. Richt.	4	6	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	rr	...	r	...
CLASS PHAEOPHYCEAE																												
Mallomonas caudata Iwanoff	4	7	...	...	...	...	rrr	...	...	...	rr	...	...	...	...	...	...	rrr	rr	...	...	...	...	ss	rrr	r	r	rr
Chrysosphaerella longispina Lauterb	5	1	ss	...	...	...	...	ss	...	...	...	...	...	r	rr	...	...	...	...	...	...	...	...	...	...	cc	...	r
Synura uvella Ehr.	5	2–3	cc	r	...	...	...	rrr	...	...	rr	cc	c	s	rr	...	rr	...	...	...	...	...	...	rr	r	s	sss	sss
Synura Adamsii sp. nov.	5	4–5	...	...	...	...	...	...	...	...	...	...	...	rr	r	...	...	...	...	...	...	...	...	...	...	...	...	...
Uroglenopsis americana (Calk.) Lemm.	5	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	sss	...	...	...	...	...	...	...	...
Dinobryon bavaricum Imhof	5	7	...	...	c	...	...	s	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Dinobryon stipitatum Stein	...	...	...	...	...	...	...	...	...	...	...	sss	ss	ss	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Dinobryon setularia Ehr.	6	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	ss	...	r	...	cc
Dinobryon divergens Imhof.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	s	...
Phaeococcus planctonicus var. *ovalis* G. M. Smith	6	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	rr	...	ss
CLASS HETEROKONTEAE																												
Botryococcus Braunii Ktz.	6	3	rr	...	rrr	r	rrr	...	...	...	...	rrr	r	...	sss	...	s	rrr	r	rr	...	...	...	...	rrr	rrr	...	...
Ophiocytium capitatum Wolle	6	4–5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	...	...	...	...	...	...	...	...
CLASS CHLOROPHYCEAE																												
Order Volvocales																												
Pandorina morum Bory	6	6	...	rrr	rrr	rrr	rrr	...	...	...	...	...	...	...	...	...	...	...	rrr	rrr	rr	...	rrr	...	rrr	...	...	rr
Eudorina elegans Ehr.	6	7	rr	rrr	rr	...	rr	rrr	...	...	...	c	ccc	rr	...	...	...	rrr	r	rrr	rr	aaa	rr	...	rr	rr	...	rr
Volvox aureus Ehr.	6	8	rrr	...	...	...	...	...	...	...	...	rr	rr	rr	rrr	...	...	...	rr	...	...	...	...	...	...	rrr	...	rrr
Volvox globator L.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	s	...	rr	rrr	...	...	...	...	...	...	...	...
Order Protococcales																												
Gloeocystis gigas (Ktz.) Lag.	7	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	rrr	...
Sphaerocystis Schroeteri Chod.	7	2	rr	rr	r	r	sss	...	...	...	...	ss	sss	rrr	...	rrr	...	sss	...	...	sss	...	rrr	rrr	rr	rr	...	r
Gloeocystopsis limneticus G. M. Smith	7	3–5	rrr	...	...	...	...	...	...	...	...	...	...	...	rr	...	...	...	...	...	...	...	...	...	...	rrr	...	...
Asterococcus limneticus G. M. Smith	7	6	...	...	...	...	...	rrr	...	...	...	rr	rr	rr	...	...	r	ss	rr	...	rr	...	...	...	...	ss	r	rr
Dictyosphaerium pulchellum Wood	7	7	rrr	sss	r	rrr	ss	...	...	...	...	...	...	...	...	...	...	cc	rrr	...	...	...	rr	...	rrr	...	...	...
Dimorphococcus lunatus A. Br.	7	8	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	rrr	...	...	rr
Westella botryoides (W. West) de Wild.	7	9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	rrr	rrr	...	...	...	rrr	...	rrr	...	...	...
Oocystis lacustris Chod.	8	1	...	sss	rrr	rrr	...	...	...	...	...	rrr	rr	...	...	...	...	...	rrr	...	rrr	...	...	...	rrr	rrr	...	...
Nephrocytium Agardhianum Naeg.	8	2–3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...
Tetraedron muticum (A. Br.) Hansg.	8	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...
Tetraedron trigonum (Naeg.) Hansg.	8	5	...	...	rr	...	rr	...	...	...	...	...	...	rrr	...	...	...	...	r	...	...	...	...	...	...	...	...	...
var. *gracile* (Reinsch) de Toni	8	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	rrr	...
Tetraedron regulare var. *incus* Teiling	8	7	...	rrr	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...
var. *torsum* (Turn.) Brunnth.	8	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...
Tetraedron gracile (Reinsch) de Toni	8	9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...
Tetraedron lobulatum (Naeg.) de Toni	8	10–12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...
var. *polyfurcatum* G. M. Smith	8	13	...	...	sss	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...
Tetraedron limneticum Borge	8	14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	rr	...	...	...	...	...
Tetraedron planctonicum G. M. Smith	8	15	...	rr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Micractinium pusillum Fresen.	9	1–2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...
Errerella bornhemiensis Conrad	9	3–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	rrr	...	...	...	...	...	...	...
Pachycladon umbrinus sp. nov.	9	5–7	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	rr	...	...	...	...	...	...	...	...	...
Selenastrum gracile Reinsch	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	rrr	...	rr	...	...	...
Selenastrum Bibraianum Reinsch	10	1	...	rrr	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Ankistrodesmus falcatus (Corda) Ralfs	10	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	rrr	...	...	...
var. *acicularis* (A. Br.) G. S. West	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Schroederia setigera (Schröd.) Lemm.	10	3–5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	...	...
Closteriopsis longissima (Schröd.) Lemm.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	rrr	...	...	...	...	...
Quadrigula Pfitzeri (Schröd.) G. M. Smith	10	6	...	...	rrr	rrr	...	...	...	...	...	...	...	...	cc	...	...	...	rr	...	...	...	...	...	...	ss	r	...

TABLE 5.—SHOWING THE DISTRIBUTION OF THE PLANKTON ALGAE IN THE LAKES OF PALISADES PARK—*Continued*

	Plate	Figure	Barnes	Cedar	Cranberry	Cromwell	Echo	Forest	Green	Highland	Island	Kanahwauke (Upper)	Kanahwauke (Lower)	Little Dam	Little Long	Long	Mine	Mombasha	Nigger	Popolopen	Portage	Queensboro	Rockland	Shepard	Stahahe	Summit	Twin (Upper)	Twin (Lower)
	p.	f.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Order Protococcales — (*Continued*)																												
Elaktothrix gelatinosa Wille	10	7	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...
Kirchneriella lunaris (Kirchn.) Möbius	...	...	rrr	...	...	...	...	...	...	...	rrr	rr	rrr	rr	...	...	...	c	rr	rrr	rrr	...	...	...	...	rrr	...	...
var. *Dianae* Bohlin	10	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	rr	...
Kirchneriella obesa (W. West) Schmidle	10	9	rrr	...	...	...	...	...	...	...	...	rr	r	...	...	...	...	...	rrr	...	...	...	...	...	rrr	rrr	...	...
Kirchneriella elongata G. M. Smith	10	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...
Crucigenia rectangularis (Naeg.) Gay	11	1	...	...	...	rrr	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	rrr	rrr	...	...
Crucigenia irregularis Wille	11	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	...
Crucigenia truncata G. M. Smith	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	...	...
Crucigenia apiculata (Lemm.) Schmidle	11	3–4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	ss	...	...	...
Crucigenia quadrata Morren	11	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...
Scenedesmus obliquus (Turp.) Ktz	11	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...
Scenedesmus arcuatus Lemm	11	7	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	...	...	...	...	...	...	...	...	...	...	...	...
var. *platydisca* G. M. Smith	11	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...
Scenedesmus armatus (Chod.) G. M. Smith	11	9–10	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	rrr	...	...	...	rr	...	...	rrr	...	...
Scenedesmus brasiliense Bohl	11	11–12	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	rrr	...	rrr	...	...	...	rrr	...	rr	rrr	rr	...
Scenedesmus denticulatus Lag	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	rrr	rrr	...
Scenedesmus longus var. *Naegelii* (Breb.) G. M. Smith	11	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	rrr	rrr	...
Scenedesmus abundans (Kirchn.) Chod	11	14	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...
Scenedesmus quadricauda (Turp.) Breb	11	15	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...
var. *longispina* (Chod.) G. M. Smith	11	16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	rrr	...	...
var. *quadrispina* (Chod.) G. M. Smith	11	17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...
Coelastrum microporum Naeg	10	11	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	rrr	rrr	...	...	...	...	...	rrr	rrr	...	...
Coelastrum cambricum Arch	10	12	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	r	...	rrr	...	rrr	...	...	rrr	...	...
Coelastrum reticulatum (Dang.) Senn	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...
Sorastrum americanum (Bohl.) Schmidle	10	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rr	...	...	...
Pediastrum araneosum Racib	12	6	...	...	rrr	...	...	...	...	...	...	...	...	...	rrr	...	...	...	rrr	...	rrr	...	rrr	...	...	rr	...	rrr
Pediastrum Boryanum (Turp.) Menegh	12	7	...	...	...	rrr	rrr	...	...	...	...	...	...	...	...	...	rrr	rrr	rrr	...	...	...	rrr	...	...	rrr	...	...
var. *longicorne* Racib	12	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...
Pediastrum duplex Meyen	12	9–10	...	...	r	rrr	...	...	...	...	...	...	...	...	...	...	...	rr	cc	rrr	...	...	rr	...	sss	rrr	...	...
var. *clathratum* (A. Br.) Lag	...	...	...	...	...	rr	...	...	...	...	...	rr	rrr	...	...	...	...	...	...	...	...	...	...	...	rr	rrr	...	...
var. *reticulatum* Lag	12	11–13	...	rr	sss	...	rrr	rr	...	...	...	...	...	rrr	...	...	...	rr	cc	...	sss	...	...	rrr	rr	...	...	...

Pediastrum biradiatum var. *heterocanthum* var. nov.	12	14																rrr										
Pediastrum tetras (Ehr.) Ralfs																		rrr				rrr		rrr				
Characium stipitatum (Bachm.) Wille	11	18	rr			rr											rrr		rr	r					rrr		
Characium curvatum G. M. Smith	11	19													rr												
Characium gracilipes Lambert	12	1–5																								ss	
Order Conjugales																												
Spirogyra sp.																								rrr		rrr	
Mougeotia sp.											rrr				rr									rrr			
Gonatozygon aculeatum Hast.	13	1																			rrr						
Spirotaenia condensata Breb.	13	2				rrr																					
Closterium lineatum Ehr.	13	3																	rr								
Closterium acerosum (Schrank) Ehr.	13	4–5													rrr					rrr							
Closterium angustatum Hantzsch															rrr												
Closterium macilentum Breb.	13	6					rrr												rrr								
Closterium setacerum Ehr.																rrr											
Closterium Kuetzingii Breb.	13	7												rrr	rrr				rrr								
Pleurotaenium Ehrenbergii (Breb.) d By.	13	8														rrr	rrr										
Pleurotaenium subcoronulatum var. *detum* W. & G. S. West	13	9–10													rrr						rrr					rr	
Euastrum pinnatum Ralfs	14	1										rrr													rrr		
Euastrum pulchellum Breb.	14	2			rrr																						
Euastrum verrucosum var. *alatum* Wolle	14	3																			rrr						
var. *reductum* Nordst.						rrr																					
Micrasterias rotata (Grev.) Ralfs	14	4																		rrr							
Micrasterias apiculata (Ehr.) Menegh.	14	5																			rrr						
var. *fimbriata* (Ralfs) Nordst.	14	6															rrr										
var. *fimbriata* forma *spinosa* Biss.	15	1			rrr								rrr		rrr		rrr										
Micrasterias pinnatifida (Ktz.) Ralfs	15	2													rrr												
Micrasterias radiata Hass.	15	3			rrr		rrr										rrr									rrr	rrr
Micrasterias muricata (Bail.) Ralfs	15	4–5													rrr												
Micrasterias mahabuleshwarensis Hobs.	16	1													rrr												
var. *serrulata* (Wolle) comb. nov.	16	2													rrr												
Micrasterias americana (Ehr.) Ralfs	16	3										rrr			rrr									rrr		rrr	rrr
Cosmarium botrytis (Bory) Menegh.															rrr												
Cosmarium moniliforme (Turp.) Ralfs																									rrr	rrr	
Cosmarium ovale Ralfs					rrr							rrr									rrr					rrr	
Xanthidium antilopaeum var. *polymazum* Nordst.	16	4													rrr		rrr				rrr				rrr	rrr	rrr
var. *minneapoliense* Wolle	16	5																								rrr	
Xanthidium subhastiferum var. *Johnsonii* (W. & G. S. West) comb. nov.	16	6–7													rrr												
Arthrodesmus incus var. *extensus* Anderss.	16	8			rrr																						
Staurastrum brevispinum var. *Boldtii* Lag.	16	9–10													r										rr	rrr	
Staurastrum cuspidatum Breb.	16	11–12					rrr											rr									
Staurastrum curvatum W. West	17	1–2			rrr																						

TABLE 5.—SHOWING THE DISTRIBUTION OF THE PLANKTON ALGAE IN THE LAKES OF PALISADES PARK—*Concluded*

	Plate	Figure	Barnes	Cedar	Cranberry	Cromwell	Echo	Forest	Green	Highland	Island	Kanahwauke (Upper)	Kanahwauke (Lower)	Little Dam	Little Long	Long	Mine	Mombasha	Nigger	Popolopen	Portage	Queensboro	Rockland	Shepard	Stahahe	Summit	Twin (Upper)	Twin (Lower)
	p.	f.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Order Conjugales—(*Continued*)																												
Staurastrum megacanthum Lund	17	3–4	...	...	...	...	...	...	...	...	...	...	...	...	c	...	...	rr	...	...	rrr	...	...	...	...	ss	cc	...
Staurastrum trihastiferum sp. nov	17	5–6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...
Staurastrum longispinum var. *bidentatum* (Wittr.) W. & G. S. West	17	7–8	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...
Staurastrum minnesotense Wolle	18	1	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	rrr	...	...	...	...	rrr	rrr	r
Staurastrum leptocladum Nordst	18	2	...	...	cc	rrr	...	...	...	...	...	...	...	...	...	rr	...	...	...	...	...	...	...	...	...	rrr	rrr	rr
Staurastrum chaetoceras (Schröd.) G.M. Smith	18	3	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Staurastrum Johnsonii W. & G. S. West	18	4	...	...	cc	...	...	...	rrr	...	...	...	...	rrr	ss	rr	...	...	...	...	...	...	...	...	...	...	...	...
var. *triradiatum* var. nov	18	5–7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	ss	...	...	...	...	...	...	...	...	rr	...
Staurastrum paradoxum Meyen	18	8–9	...	...	...	s	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	cc	...
var. *longipes* Nordst	18	10–11	...	...	c	...	...	...	...	...	...	...	...	...	r	...	...	...	...	...	...	...	...	sss	...	rr	rr	...
Staurastrum cingulum (W. & G. S. West) G. M. Smith	18	12	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Staurastrum longiradiatum W. & G. S. West	19	1–3	...	...	rrr	r	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	rrr	...	rr	...	...
Staurastrum tetracerum var. *evolutum* W. & G. S. West	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Staurastrum lacustre G. M. Smith	19	4–5	...	...	...	...	...	...	...	...	ss	...	...	...	rrr	...	...	...	...	...	...	...	...	rrr	...	...	...	...
Staurastrum anatinum var. *curtum* G. M. Smith	19	6–8	...	...	r	...	...	...	...	...	...	rr	rrr	...	ss	...	...	...	...	...	rrr	...	...	...	...	s	ss	r
Staurastrum cerastes Lund	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...
Staurastrum pseudopelagicum var. *minor* var. nov	18	13–14	...	...	...	rr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Staurastrum pentacerum (Wolle) G. M. Smith	19	9	...	...	c	...	...	ss	...	...	...	...	...	...	ss	...	...	rrr	...	...	...	...	...	...	...	s	ss	...
var. *tetracerum* (Wolle) G. M. Smith	19	10–11	...	...	c	rrr	...	ss	r	...	rr	...	...	...	...	...	...	rrr	...	...	...	rrr	...	...	...	ss	rr	rrr
Staurastrum ankyroides Wolle	19	12–13	...	...	...	...	...	...	...	...	...	rrr	...	...	rrr	...	...	...	...	...	...	...	...	...	...	r	...	...
Staurastrum Ophiura Lund	20	1–3	...	...	...	...	...	...	...	...	...	rrr	rrr	rrr	rrr	...	...	...	...	...	...	...	...	...	...	rrr	rrr	...
Staurastrum tohopekaligense Wolle	20	6–7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	rr
Staurastrum furcigerum Breb	20	4–5	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...
Staurastrum Arctiscon (Ehr.) Lund	20	8–9	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	rrr	rr
var. *glabrum* W. & G. S. West	21	1	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	rrr	rrr	...
Staurastrum Wolleanum Butler	21	2	...	...	...	...	...	...	...	...	...	...	...	...	rrr	...	...	...	...	...	...	...	...	...	...	...	...	...

Staurastrum brasiliense var. *Lundellii* W. & G. S. West	21	3–4																					rrr			rr	rrr	rr
Sphaerozosma Aubertianum var. *Archerii* (Gutw.) W. & G. S. West	21	5																						rrr				
Onychonema laeve var. *latum* W. & G. S. West	22	1																			rrr							
Hyalotheca mucosa (Dillw.) Ehr.	22	2													rrr		rr									rrr	rrr	
Hyalotheca undulata Nordst.	22	3–4																								rrr		
Spondylosium planum (Wolle) W. & G. S. West	22	5																rrr			sss					rrr		rrr
Spondylosium pulchrum (Bail.) Arch.	22	6						rrr																		rrr		
Spondylosium moniliforme Lund.	22	7															rrr				rrr							
Desmidium cylindricum Grev.	22	8													rrr											rrr		
Desmidium Swartzii Ag.	22	9													rrr		rrr									rrr	rr	rr
Desmidium Baileyi (Ralfs) Nordst.	22	10–11																								rrr		
Gymnozyga moniliformis Ehr.	22	12													rrr												rrr	
CLASS BACILLARIEAE																												
Cyclotella antiqua W. Smith	23	1																									rr	
Cyclotella Meneghiniana Ktz.	23	2																						rr				
Cyclotella stelligera Cleve & Grunow	23	3					ss				r																	
Cyclotella comta var. *radiosa* Grunow	23	4	rrr		rr		rrr	rr		rr	rr	rr	rrr			rr		rrr	rr		rr	rr	rr	ss			rr	
Melosira crenulata (Ehr.) Ktz.	23	5			sss		r	r			rr	rr	rr														rr	rr
Melosira granulata (Ehr.) Ralfs	23	6				rr										c												
Melosira distans (Ehr.) Ktz.	23	7–8																				c						
Tabellaria fenestrata (Lyngb.) Ktz.	24	1			s	rrr	r	sss		r	cc	r	r			rr		ss			s	r					s	rr
var. *asterionelloides* Grunow	24	2									ss													rr				
var. *gracilis* Meister	23	9–10																r			ss						rr	
Tabellaria floccosa (Roth) Ag.	23	11				r				rr	ss							sss				rr						
Fragilaria crotonensis var. *prolongata* Grunow	23	13–14				rrr												s				s						
Fragilaria capunica Desm.	23	15									rrr																	rrr
var. *mesolepta* Rab.	23	16																										rrr
Synedra ulna var. *subaequalis* (Grunow) V. H.	23	22																										rrr
Synedra danica Ktz.	23	21									rrr												rr					
Synedra splendens Ktz.	23	23										rr	r															
Eunotia lunaris (Ehr.) Grunow	23	17														rrr								rrr				
Eunotia pectinalis (Dillw.) Rab.	23	18									rr																	
var. *impressa* O. M.	23	19									rr	rrr															rr	
var. *undulata* Ralfs	23	20									r																	
Asterionella formosa Hass.	24	3													cc				r									
var. *gracillima* (Hantz.) Grun.	...	...				rrr		s				ss	rr		rr	ss		ss	rrr								r	r
var. *subtilissima* Grunow	...	...			s																							
Surirella gracilis Grunow	24	4				r																						
Surirella splendida Ktz.	24	5				s		rr								rr								r				
Surirella elegans Ehr.	...	...					rr																					
Surirella gualimalensis Ehr.	24	6				ss																						

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Plate 3. Plankton Algae of Palisades Park

(All figures x 460)

PLATE 3

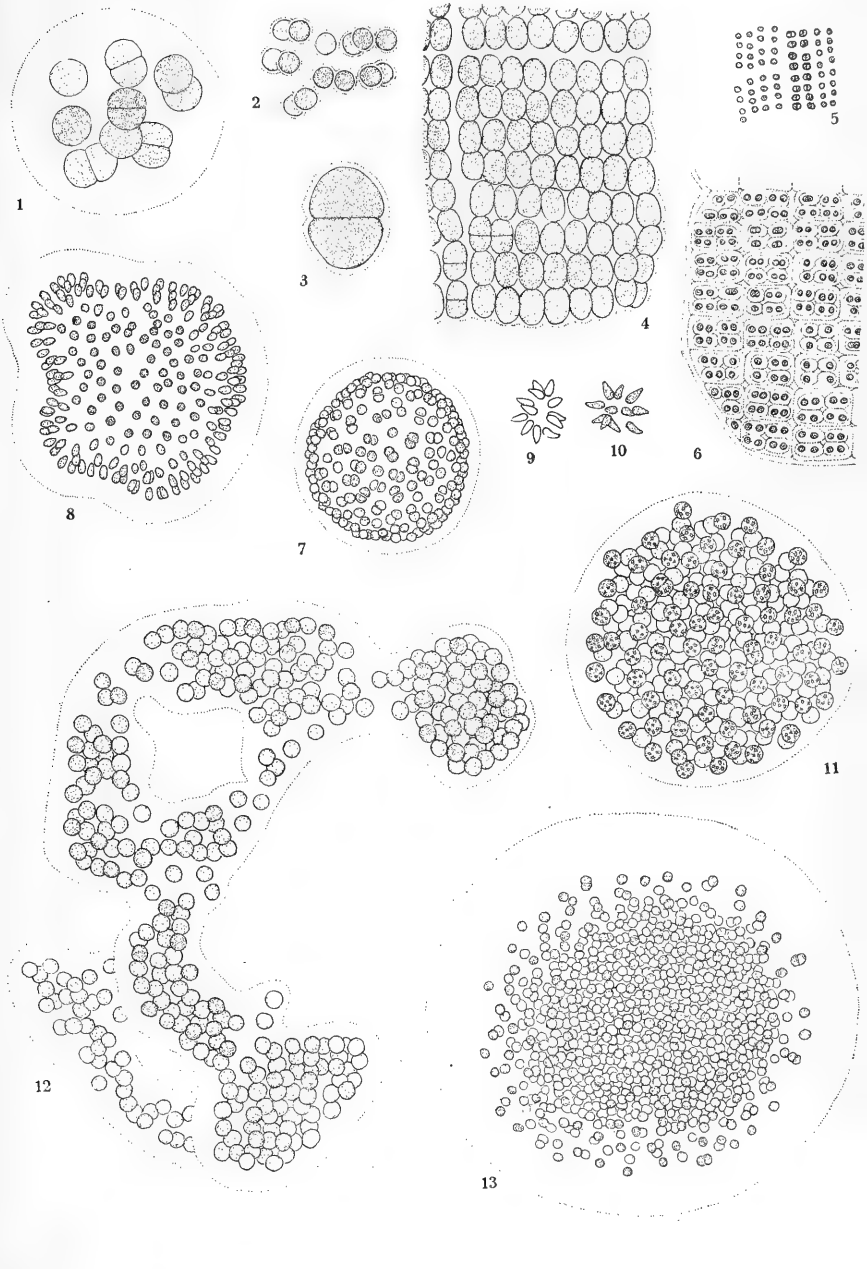
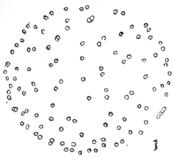


Plate 4. PLANKTON ALGAE OF PALISADES PARK

(All figures x 460)

PLATE 4



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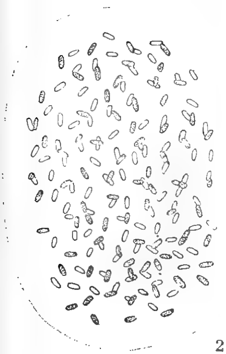

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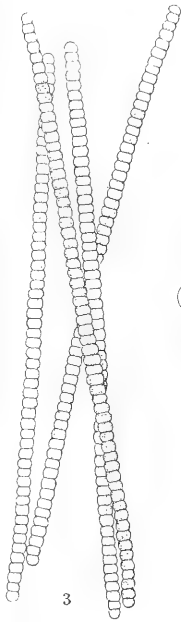

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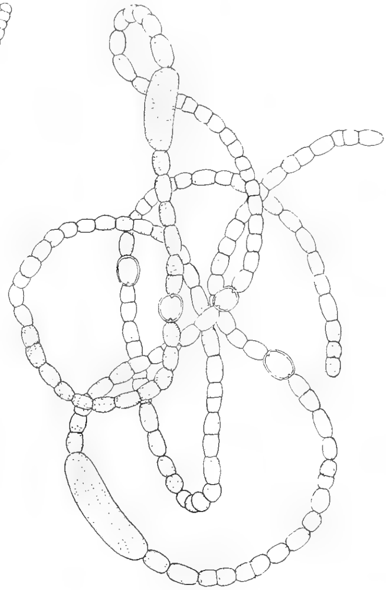

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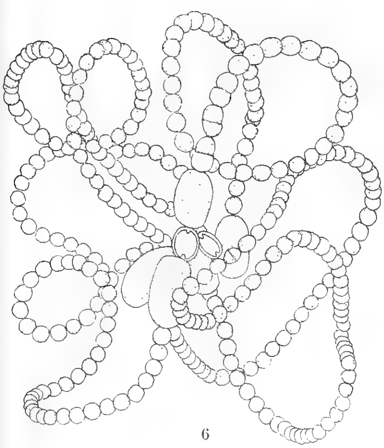

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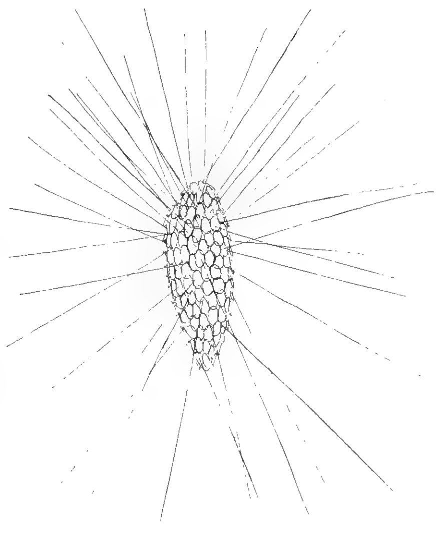
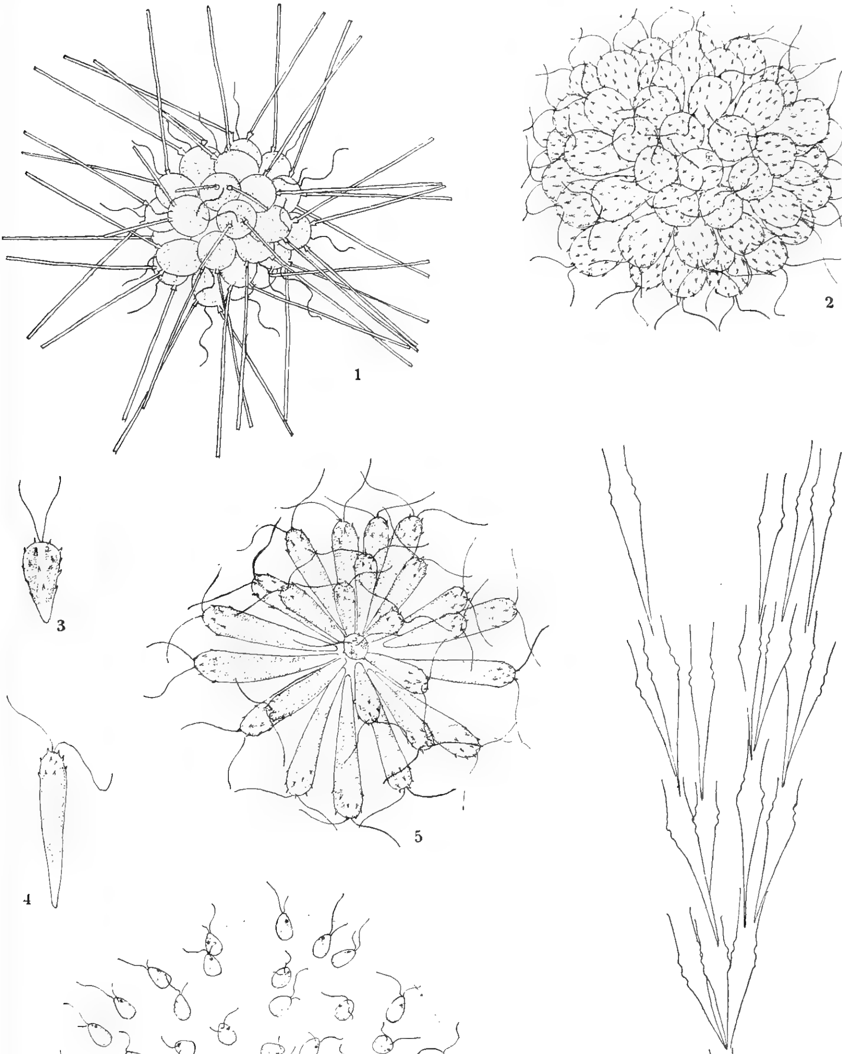


Plate 5. PLANKTON ALGAE OF PALISADES PARK

(All figures x 460)

PLATE 5



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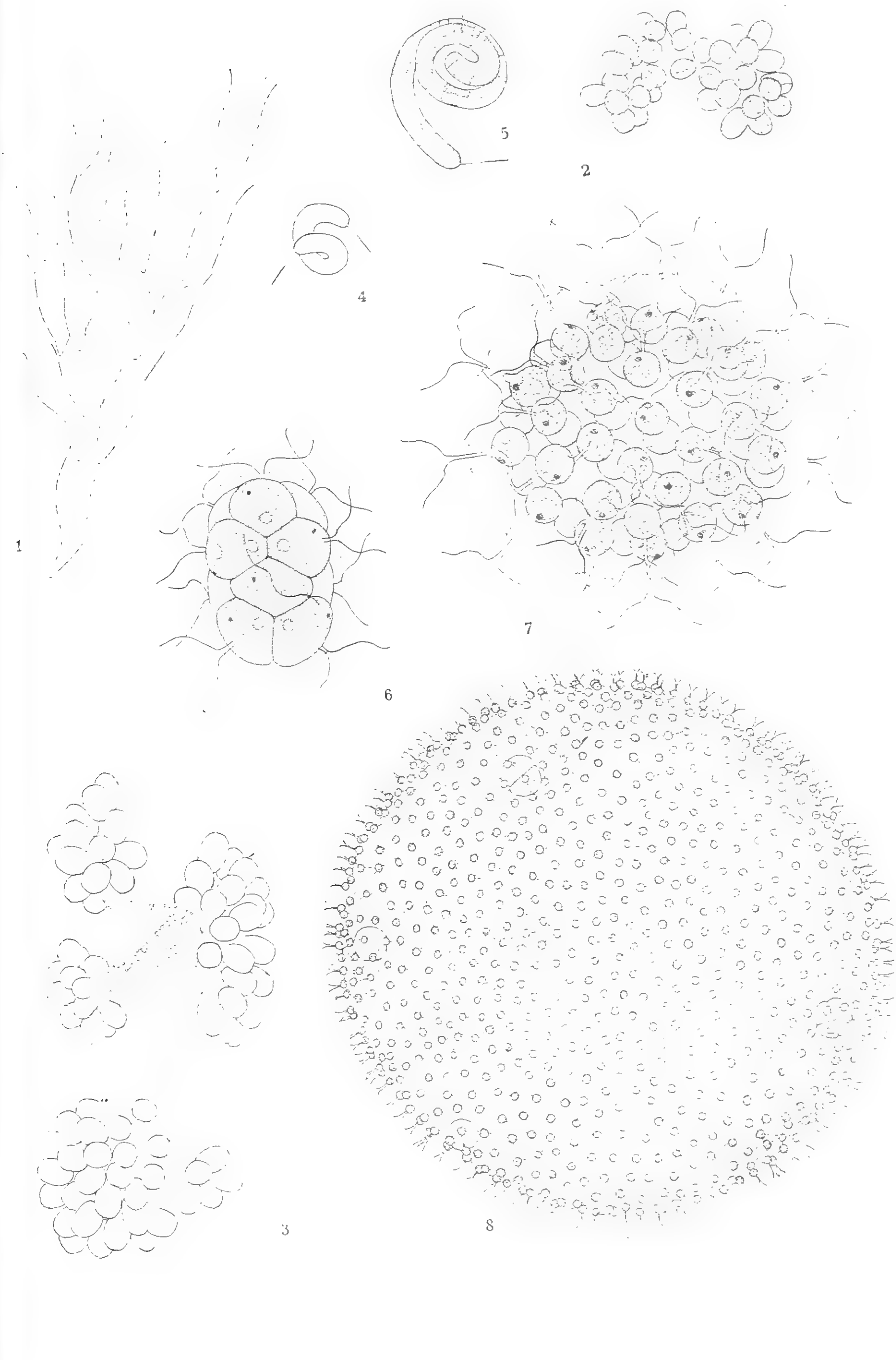
(Figs. 1–7 x 460; fig. 8 x 230)

PLATE 6



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(All figures x 460)

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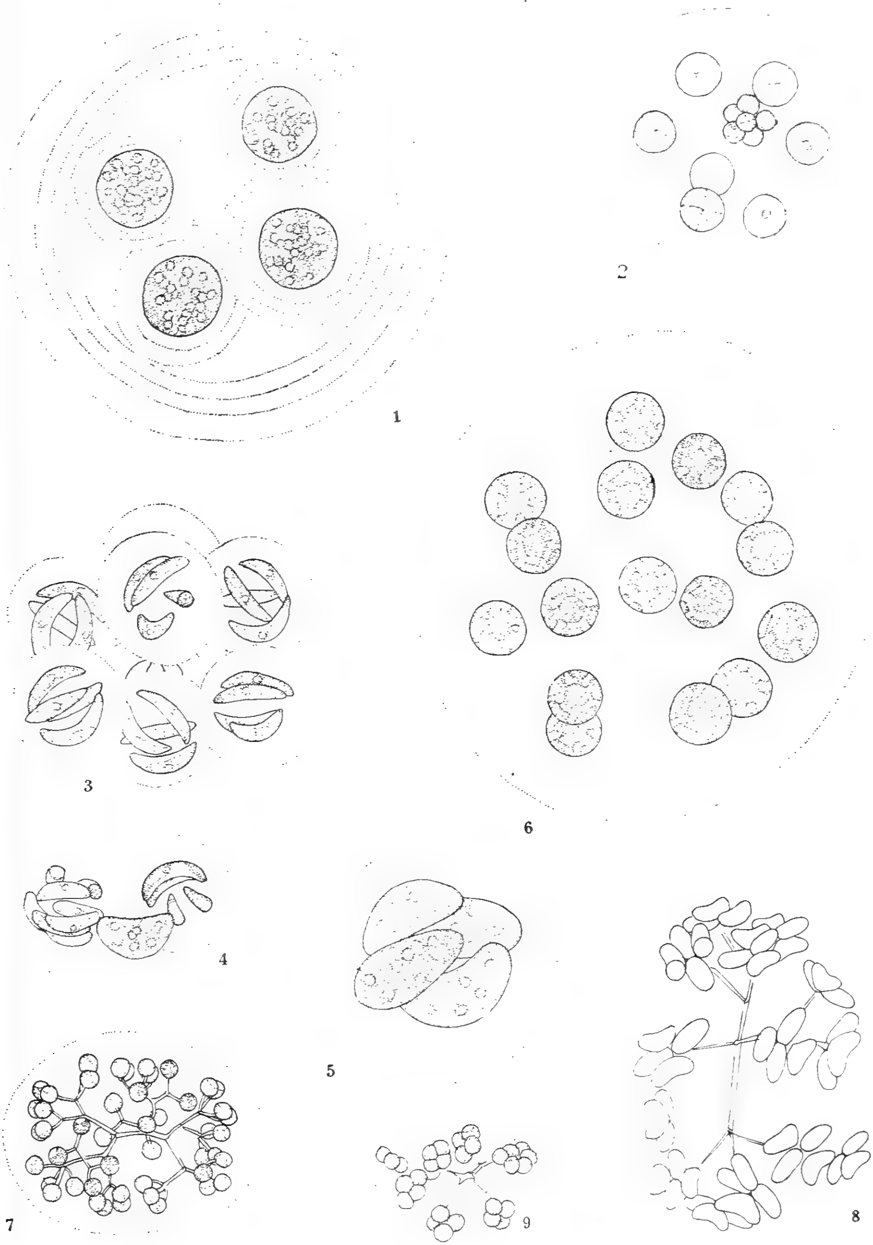

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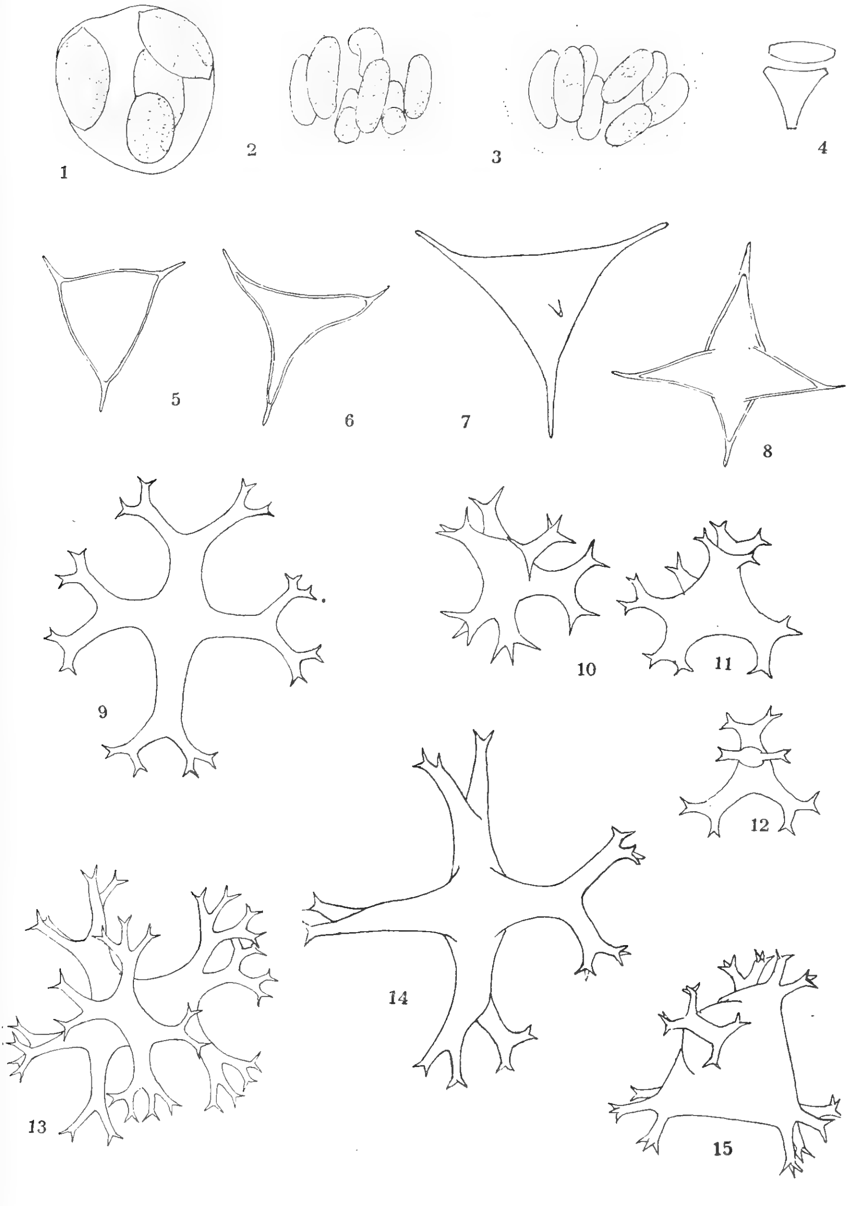

Plate 9. PLANKTON ALGAE OF PALISADES PARK

(All figures x 460)

PLATE 9

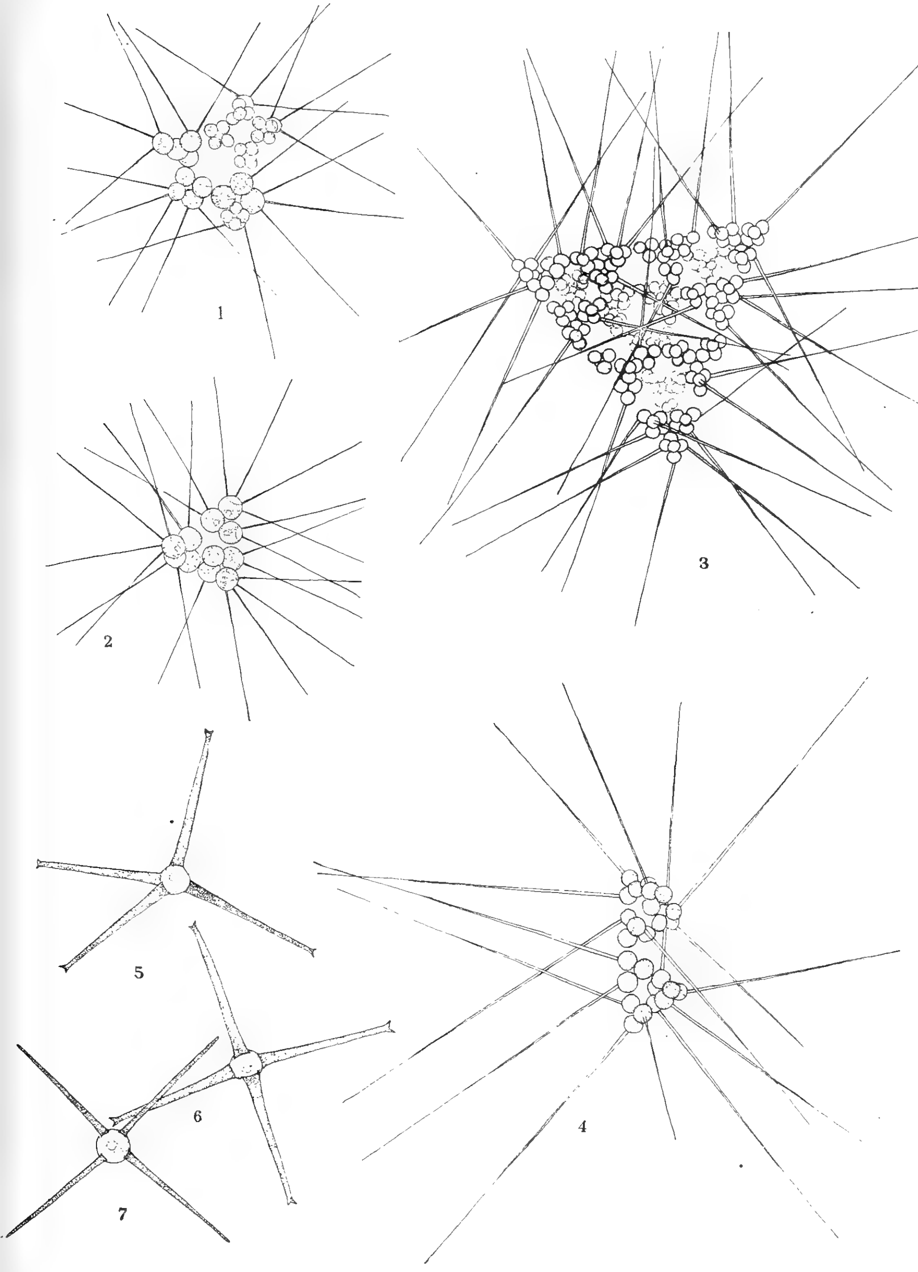

Plate 10. PLANKTON ALGAE OF PALISADES PARK

(All figures x 460)

PLATE 10

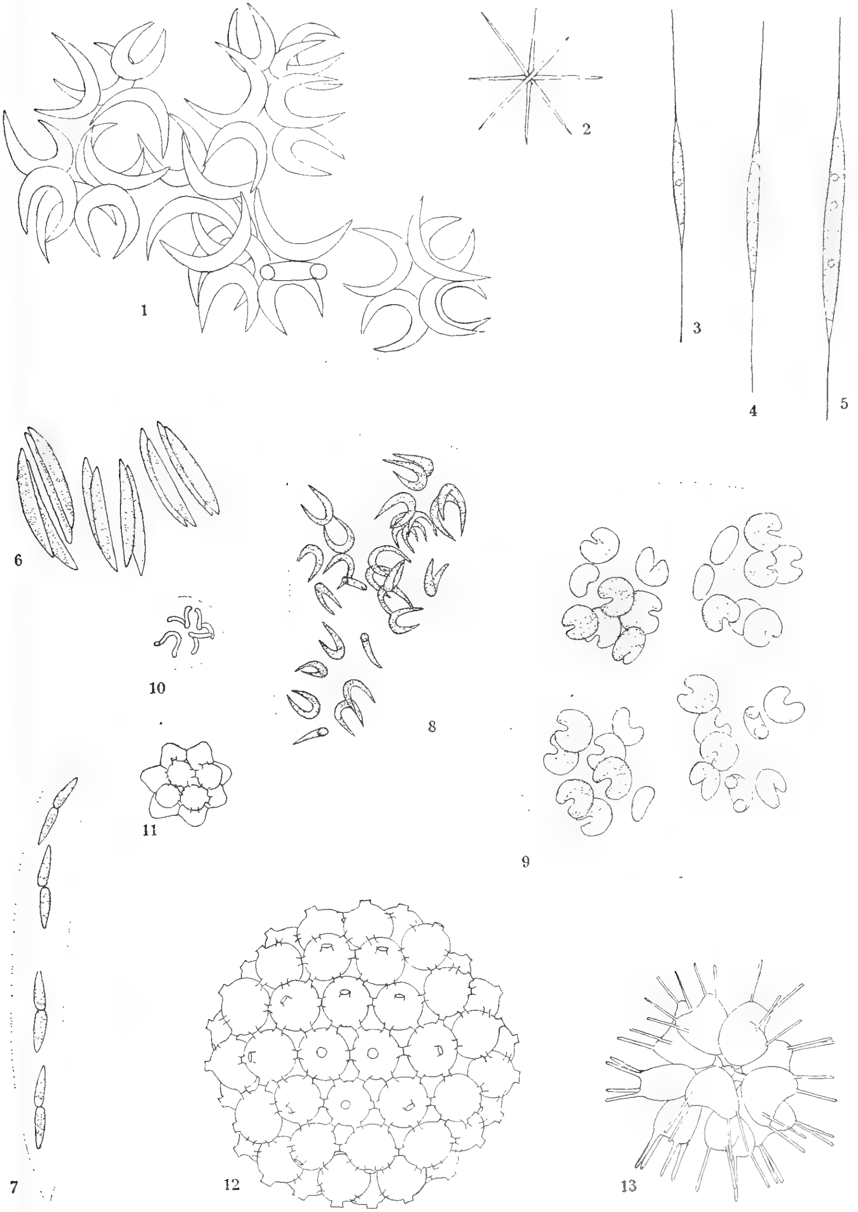

Plate 11. Plankton Algae of Palisades Park

(All figures x 680)

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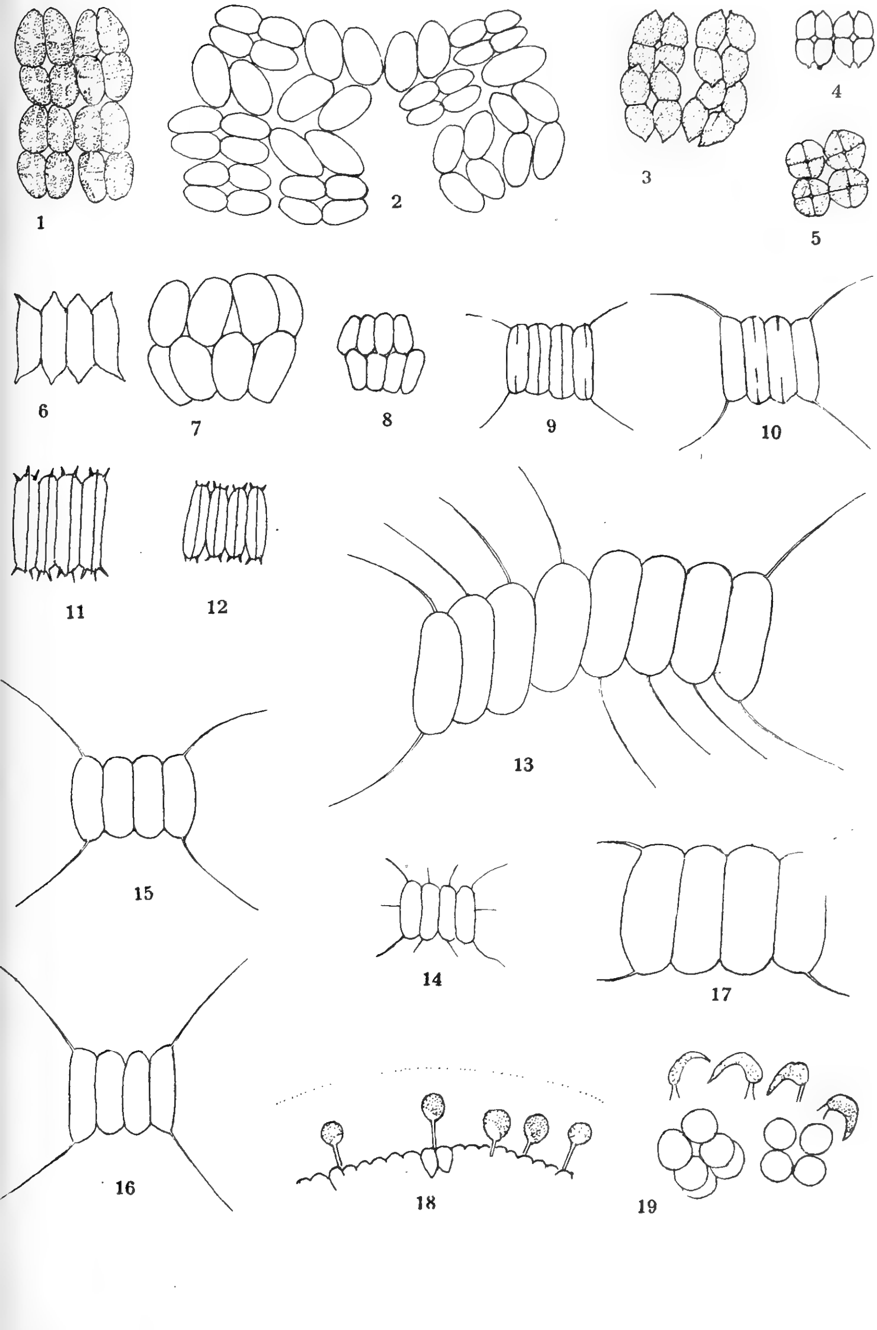

Plate 12. PLANKTON ALGAE OF PALISADES PARK

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PLATE 12

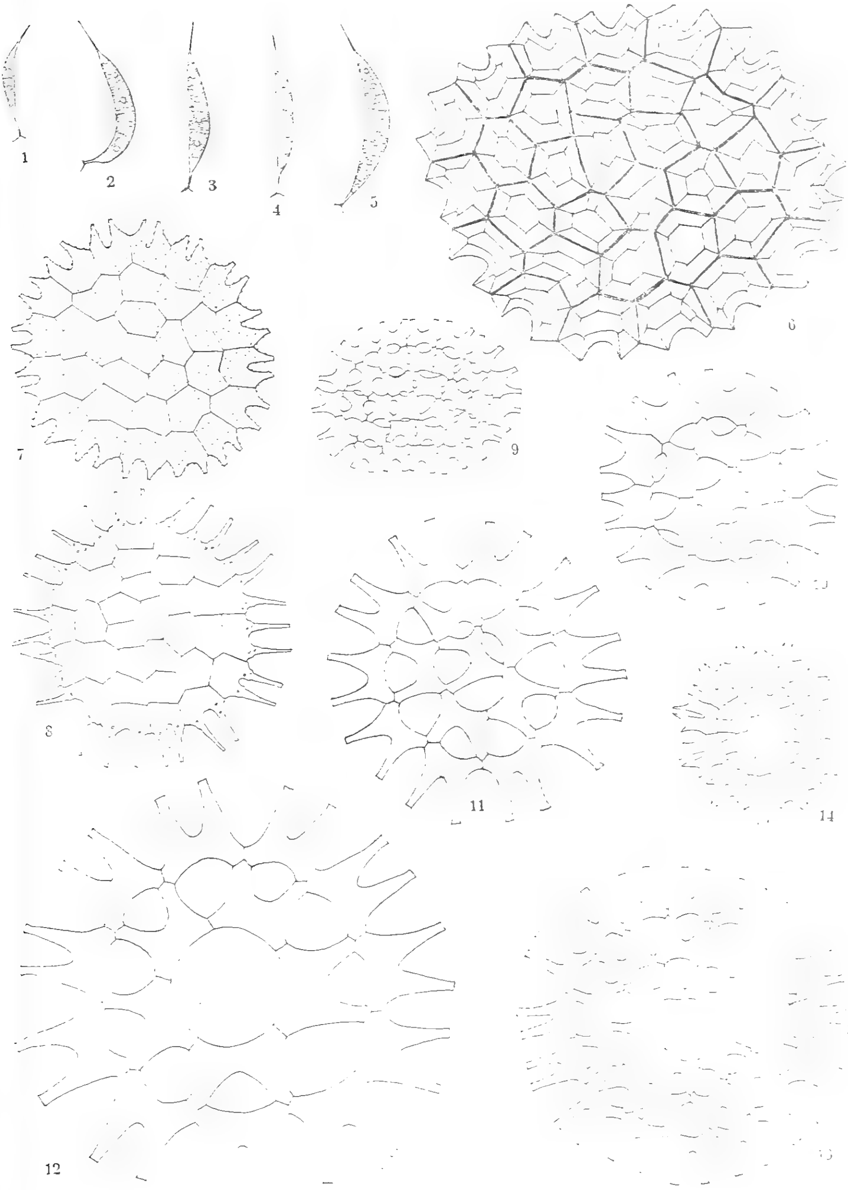


Plate 13. PLANKTON ALGAE OF PALISADES PARK

(Figs. 1–2, 7–10 x 460; figs. 3–6 x 230)

PLATE 13

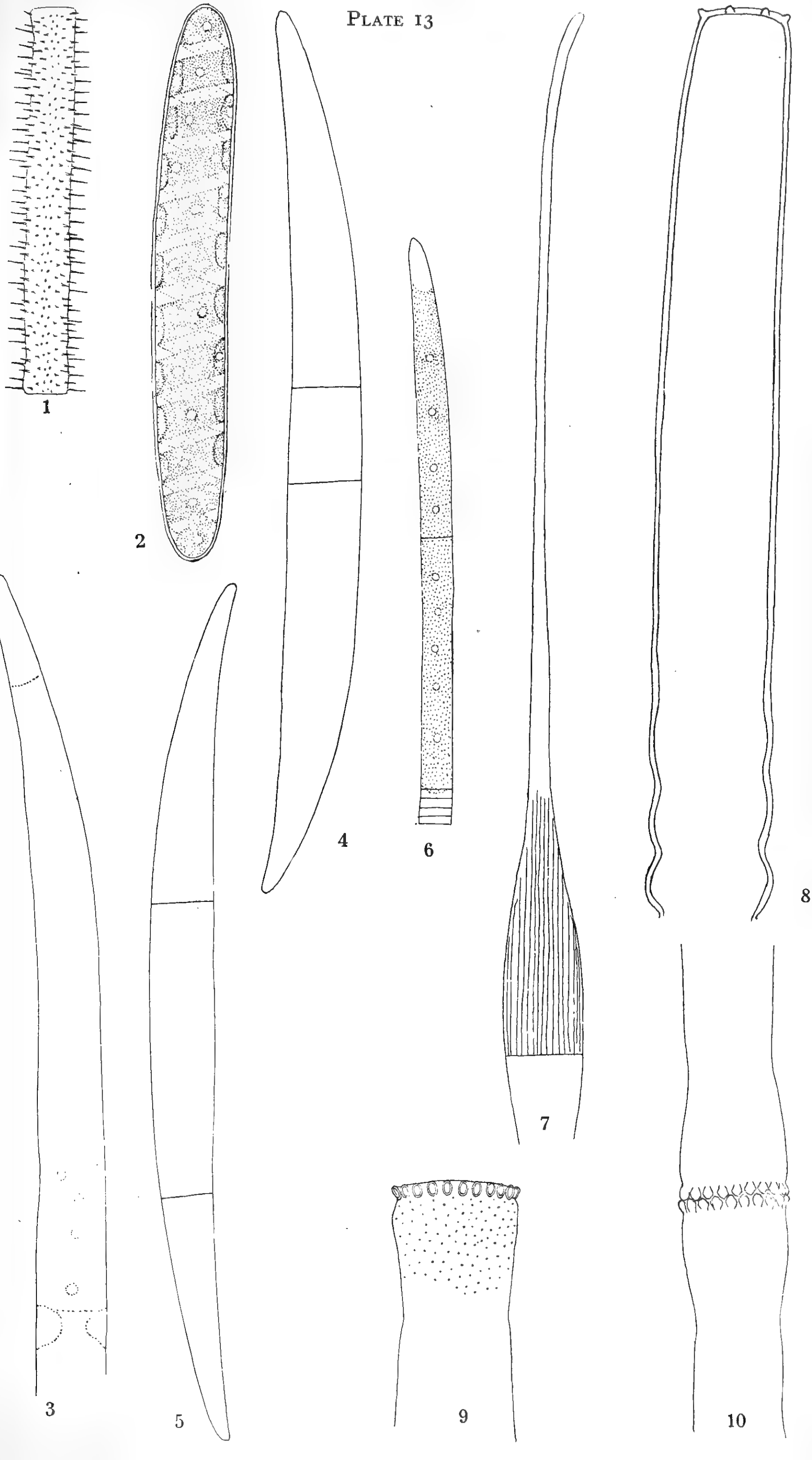
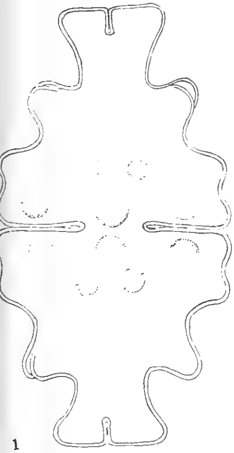


Plate 14. PLANKTON ALGAE OF PALISADES PARK

PLATE 14



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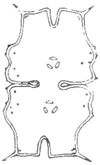

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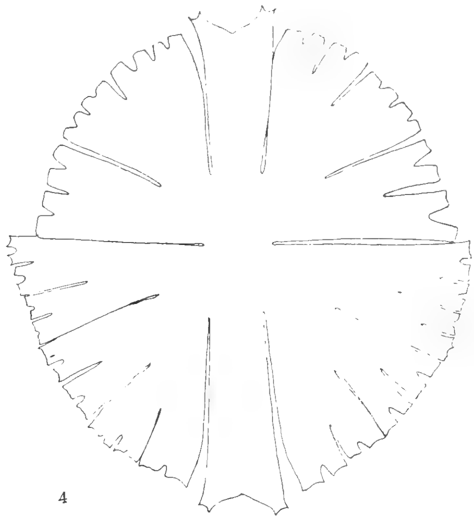

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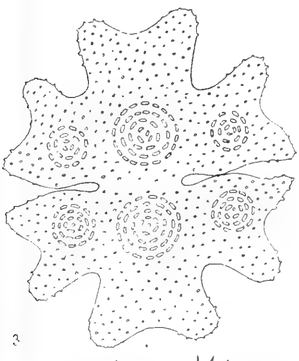

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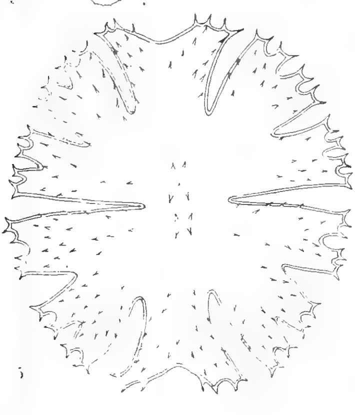

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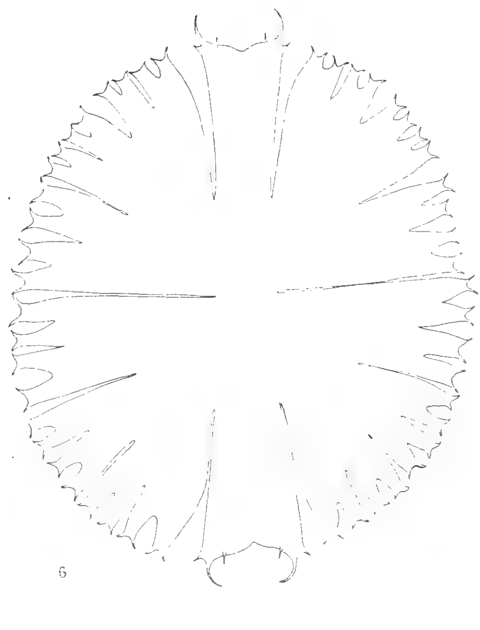

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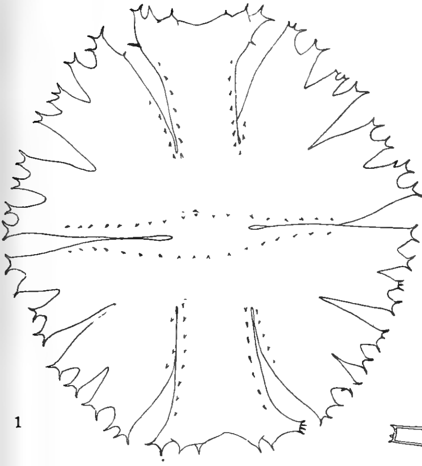
Plate 15. PLANKTON ALGAE OF PALISADES PARK

(Figs 1, 5 x 230; figs. 2–4 x 460)

PLATE 15



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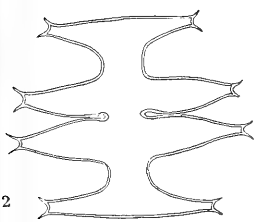

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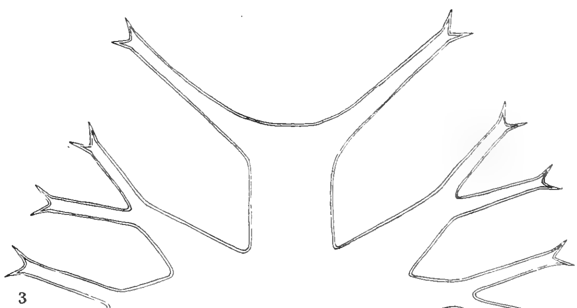

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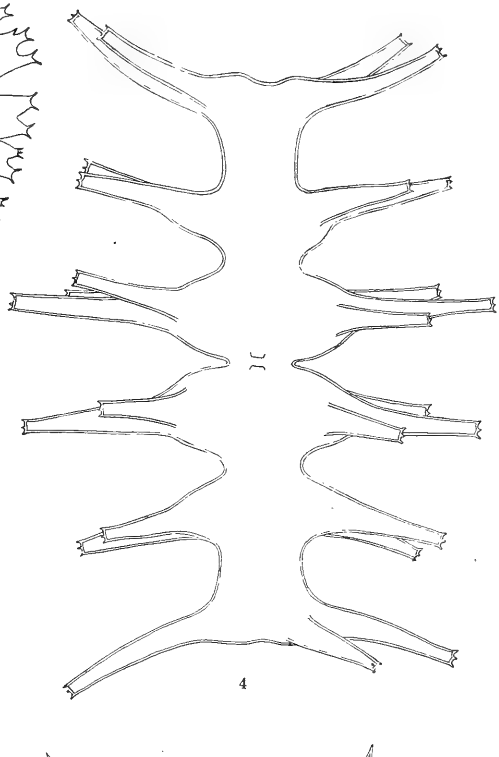

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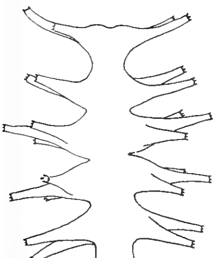

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(All figures x 460)

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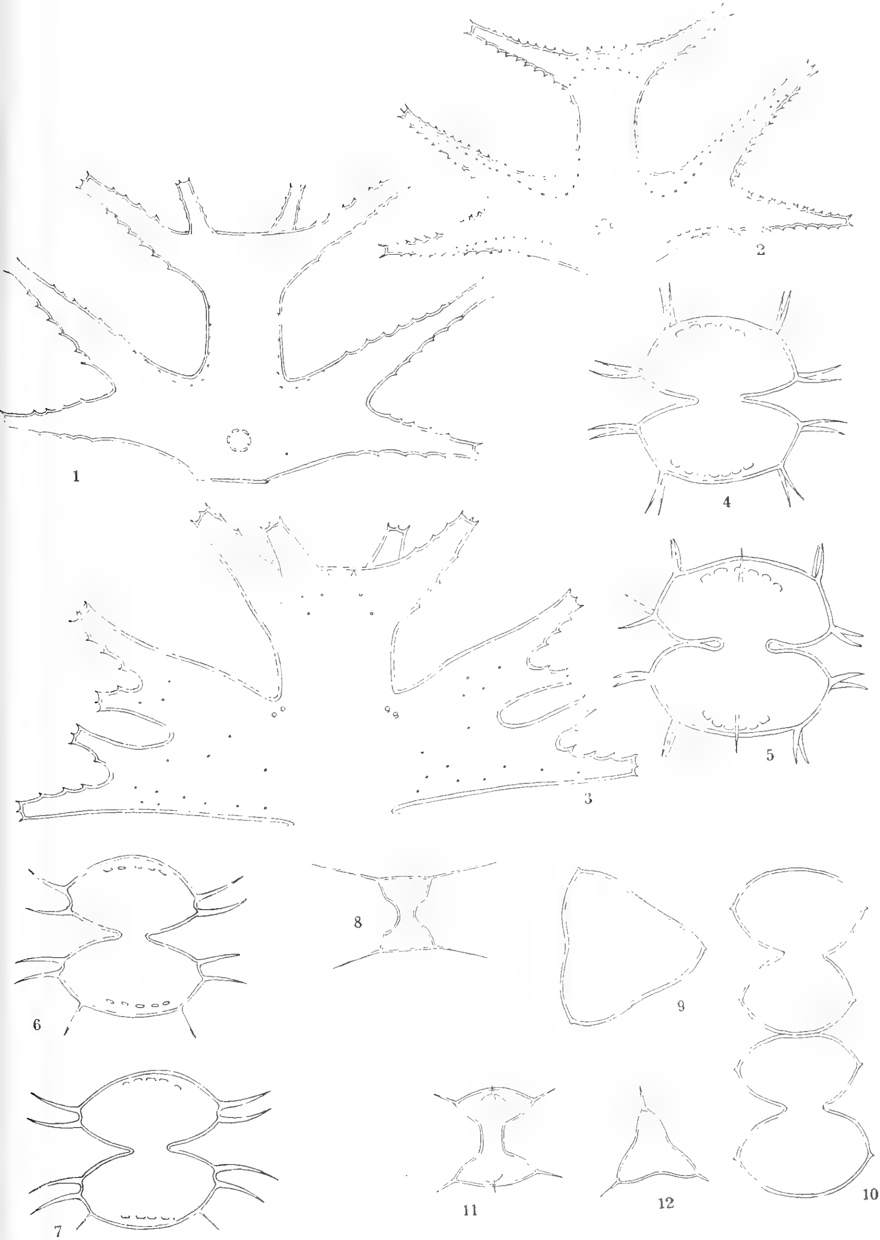

Plate 17. PLANKTON ALGAE OF PALISADES PARK

(All figures x 460)

PLATE 17

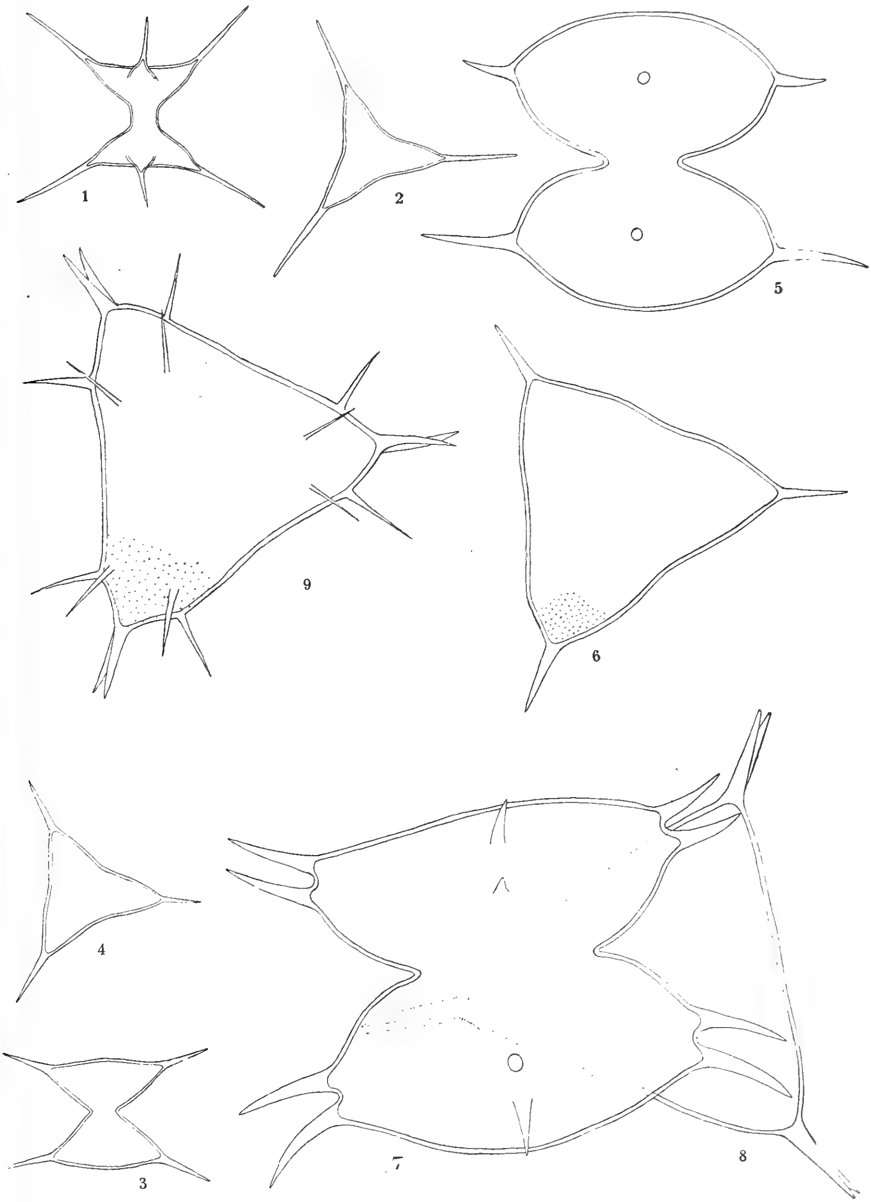

Plate 18. PLANKTON ALGAE OF PALISADES PARK

(All figures x 460)

PLATE 18

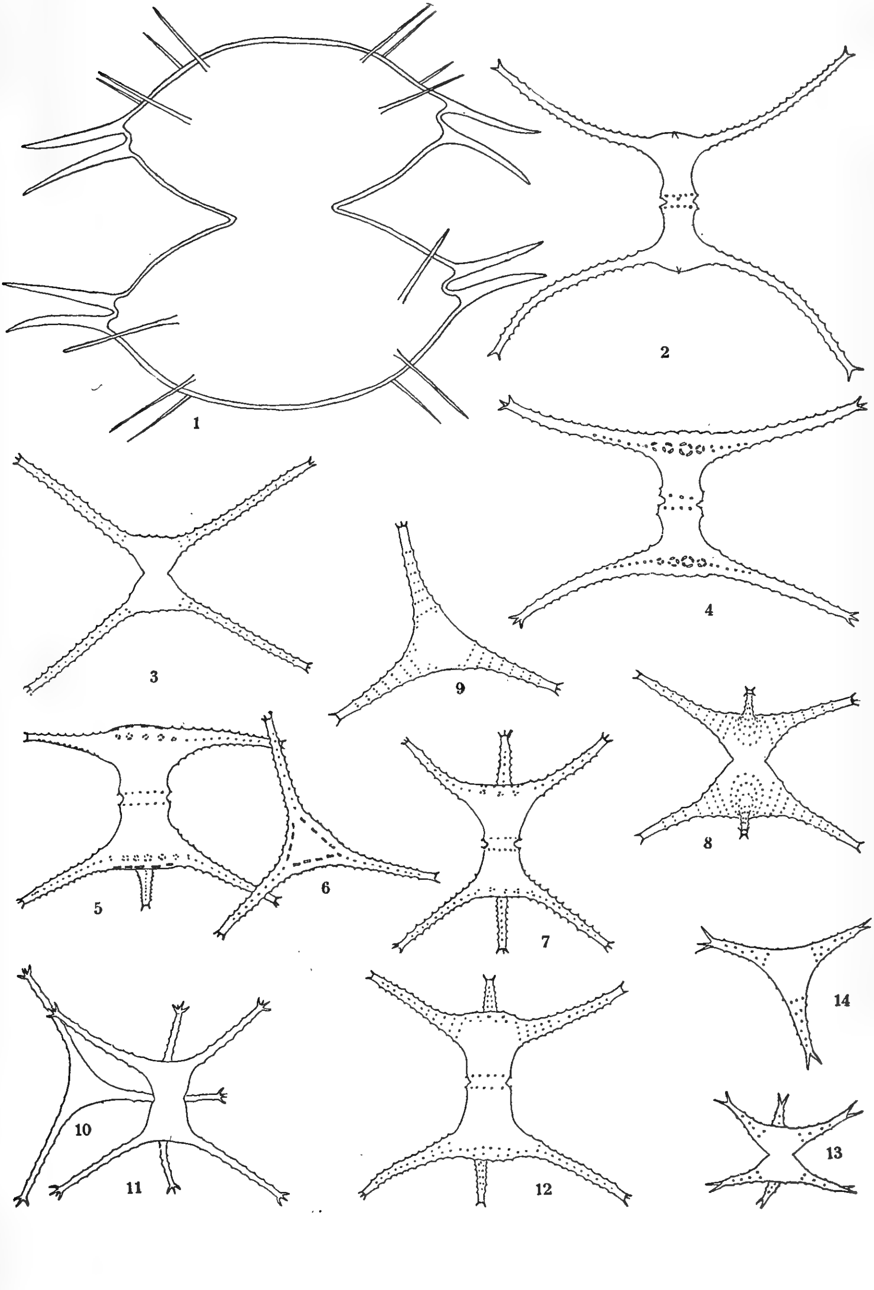

Plate 19. PLANKTON ALGAE OF PALISADES PARK

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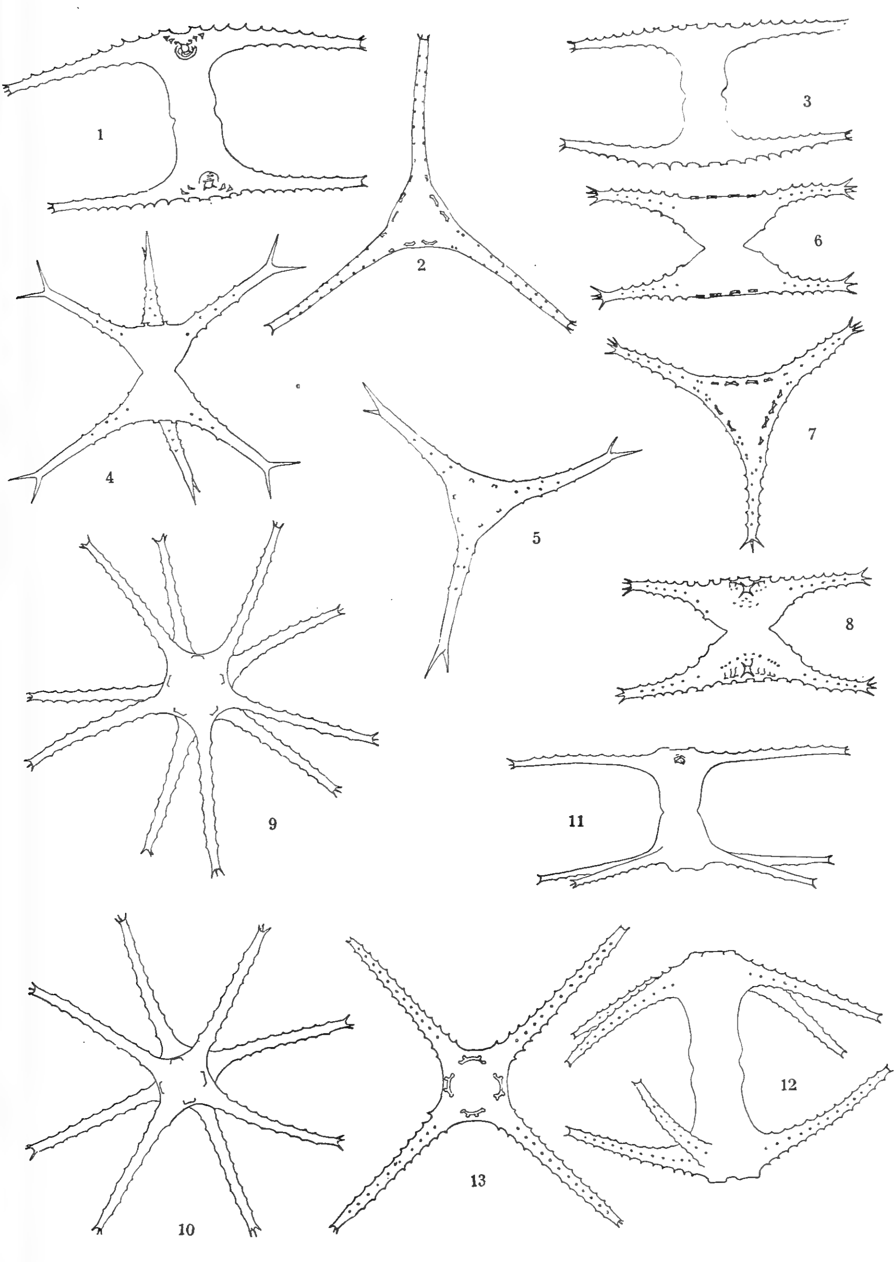

Plate 20. PLANKTON ALGAE OF PALISADES PARK

(All figures x 460)

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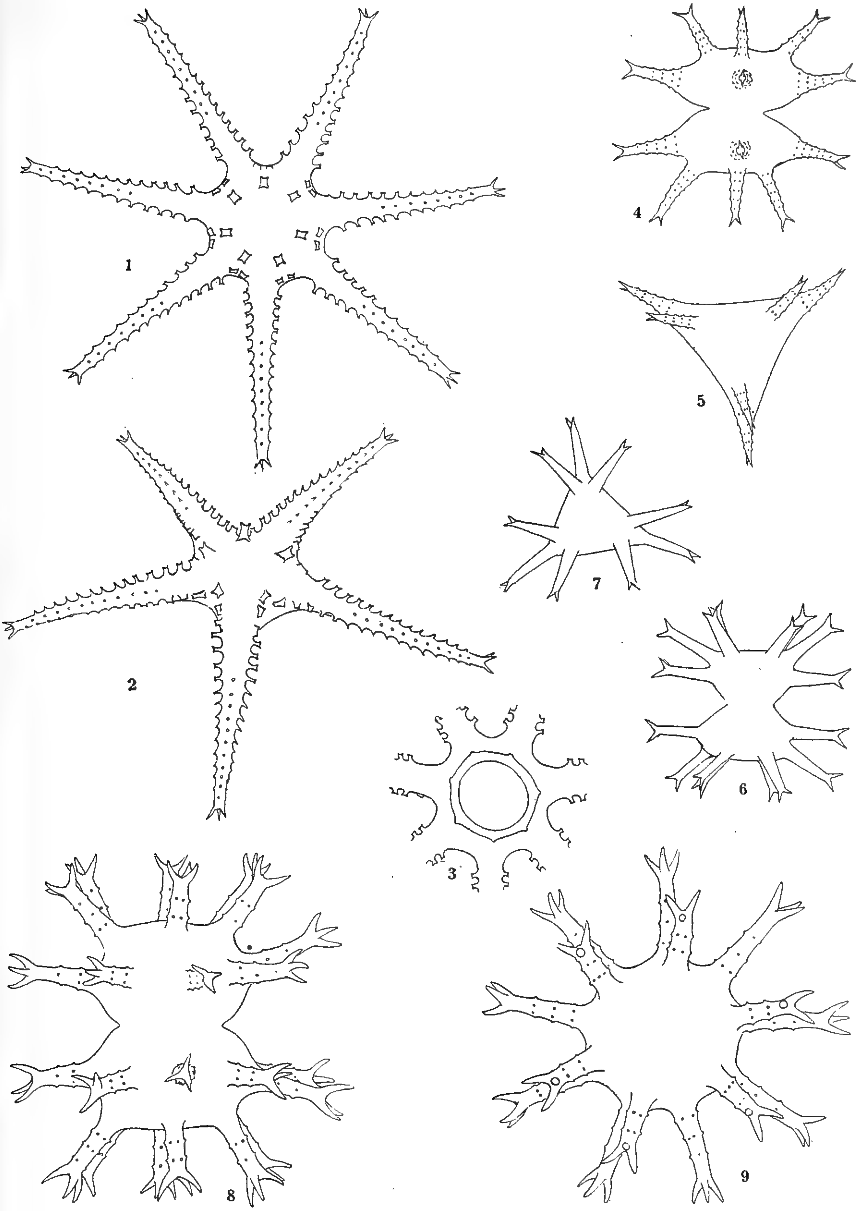

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PLATE 21

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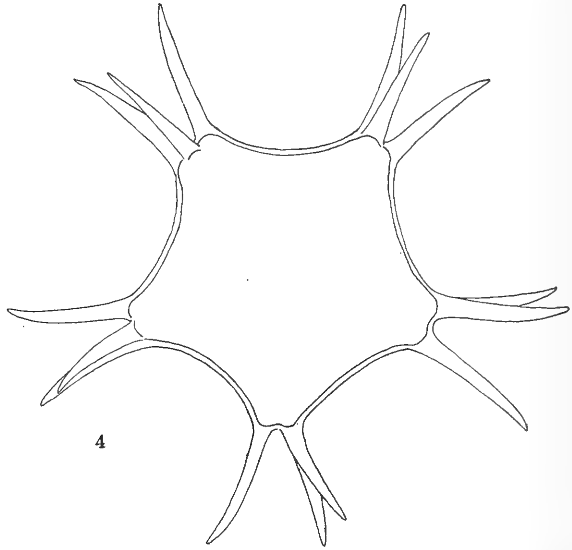

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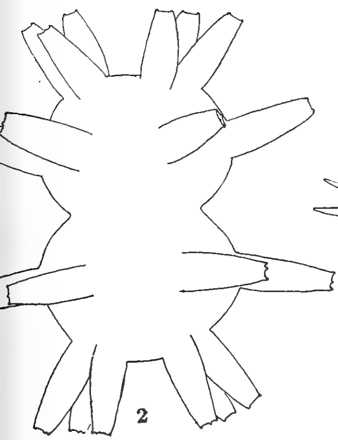

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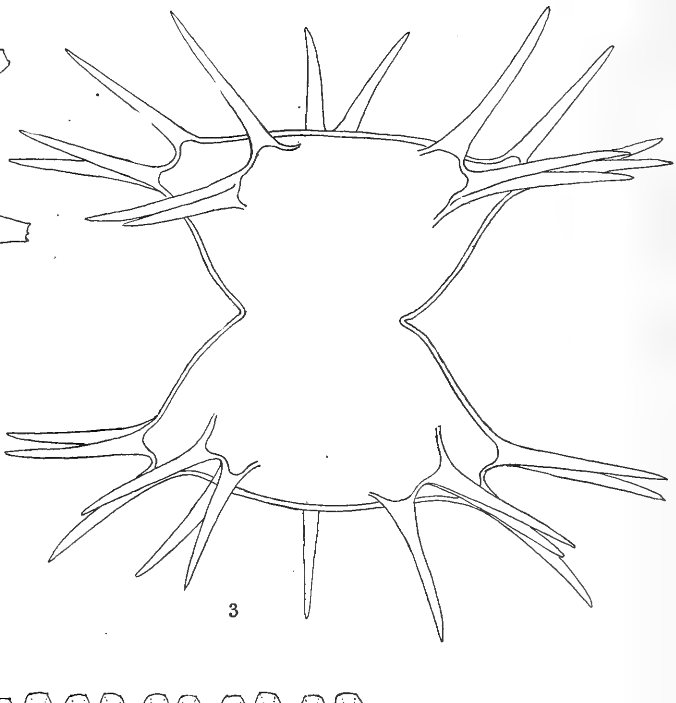

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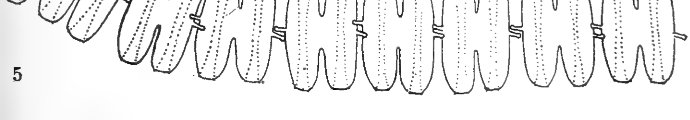

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Plate 22. PLANKTON ALGAE OF PALISADES PARK

PLATE 22

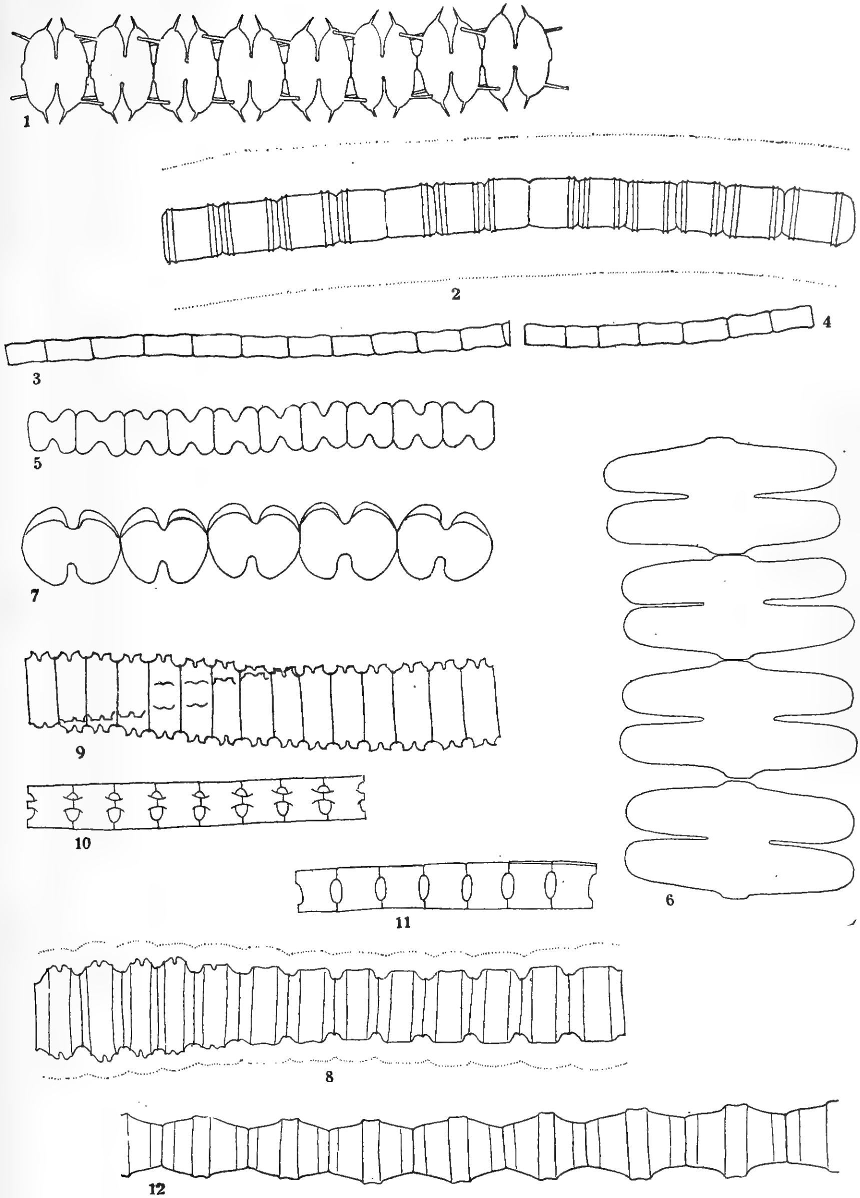

Plate 23. PLANKTON ALGAE OF PALISADES PARK

(Figs. 1–20 x 855; figs. 21–23 x 355) PAGE

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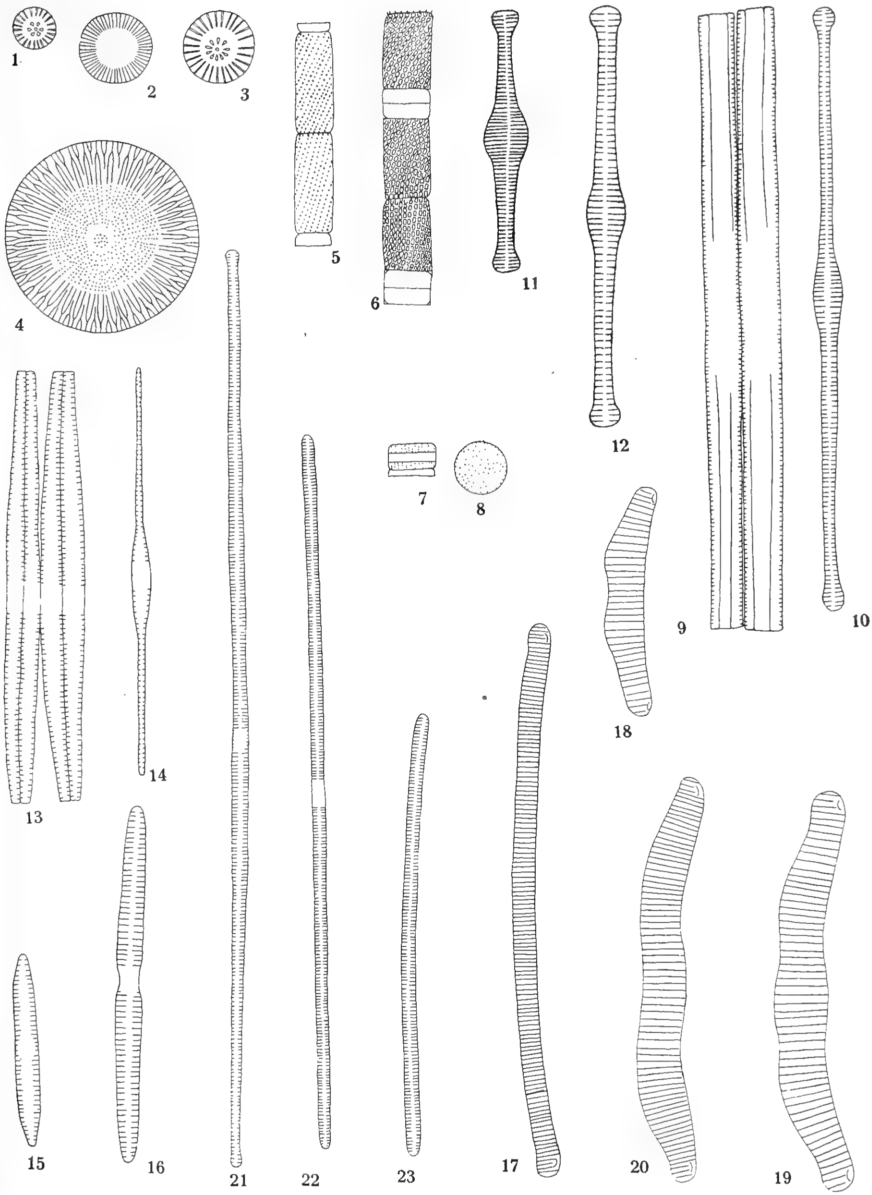
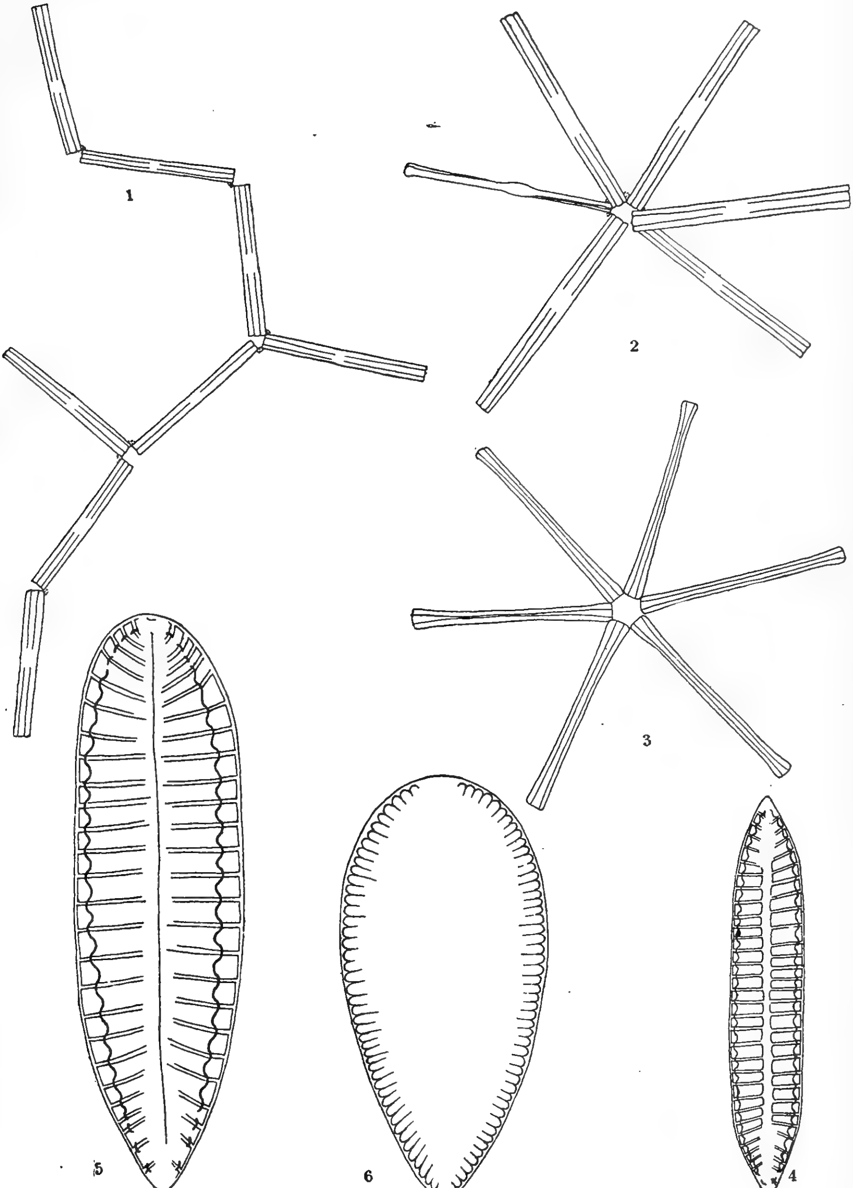


Plate 24. Plankton Algae of Palisades Park

(All figures x 460)

PLATE 24



THE ROOSEVELT WILD LIFE MEMORIAL

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The State of New York is the trustee of this wild life Memorial to Theodore Roosevelt. The New York State College of Forestry at Syracuse is a State institution supported solely by State funds, and the Roosevelt Wild Life Forest Experiment Station is a part of this institution. The Trustees are State officials. A legislative mandate instructed them as follows:

"To establish and conduct an experimental station to be known as 'Roosevelt Wild Life Forest Experiment Station,' in which there shall be maintained records of the results of the experiments and investigations made and research work accomplished; also a library of works, publications, papers and data having to do with wild life, together with means for practical illustration and demonstration, which library shall, at all reasonable hours, be open to the public." [Laws of New York, chapter 536. Became a law May 10, 1919.]

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While this Memorial Station was founded by New York State, its functions are not limited solely to the State. The Trustees are further authorized to cooperate with other agencies, so that the work is by no means limited to the boundaries of the State or by State funds. Provision for this has been made by the law as follows:

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I hereby give and bequeath to the Roosevelt Wild Life Forest Experiment Station of The New York State College of Forestry at Syracuse, for wild life research, library, and for publication, the sum of ...., or the following books, lands, etc.

Syracuse Univ. Bull. Vol. 23 MARCH, 1924 Number 7

Roosevelt Wild Life Bulletin

VOLUME 2, NUMBER 3

OF

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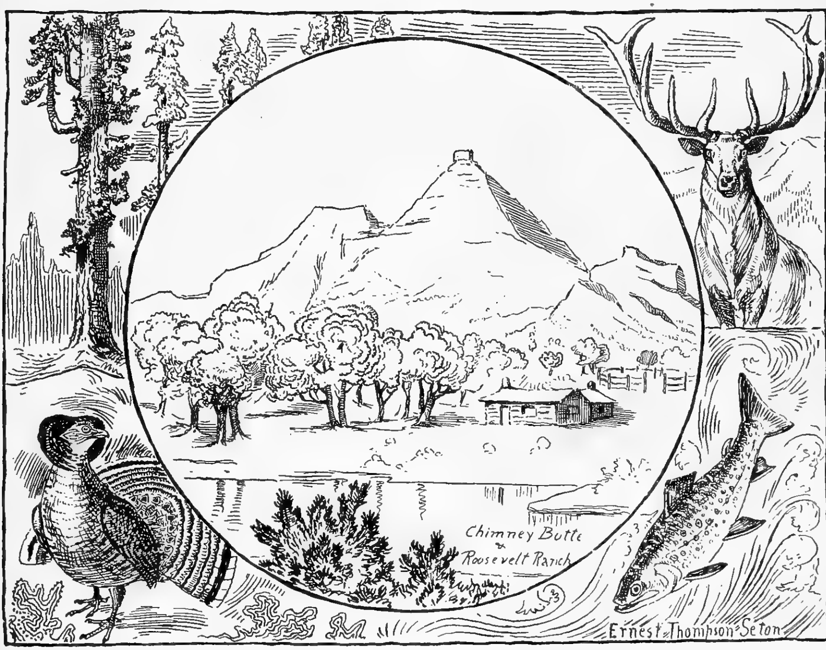

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2. **Roosevelt Wild Life Annals.**

The *Bulletin* is intended to include papers of general and popular interest on the various phases of forest wild life, and the *Annals* those of a more technical nature or having a less widespread interest.

These publications are edited in cooperation with the College Committee on Publications.

The editions of these publications are limited and do not permit of general free distribution. Exchanges are invited. The subscription price of the *Bulletin* is $4.00 per Volume of four Numbers, or $1.00 per single Number. All communications concerning publications should be addressed to

DR. CHARLES C. ADAMS, *Director and Editor,*
Roosevelt Wild Life Forest Experiment Station,
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** Resigned as Station Ichthyologist October 1, 1921.

THE RELATION OF FORESTS AND FORESTRY TO HUMAN WELFARE

"Forests are more than trees. They are rather land areas on which are associated various forms of plant and animal life. The forester must deal with all. Wild life is as essentially and legitimately a part of his care as are water, wood and forage. Forest administration should be planned with a view to realizing all possible benefits from the land areas handled. It should take account of their indirect value for recreation and health as well as their value for the production of salable material; and of their value for the production of meat, hides and furs of all kinds as well as for the production of wood and the protection of water supplies.

"Unquestionably the working out of a program of wild life protection which will give due weight to all the interests affected is a delicate task. It is impossible to harmonize the differences between the economic, the esthetic, the sporting and the commercial viewpoint. Nevertheless, the practical difficulties are not so great as they appear on the surface."

Henry S. Graves,
Former Chief Forester, U. S. Forest Service.
Recreation, Vol. 52, p. 236; 1915.

THE NECESSITY FOR FIELD INVESTIGATIONS OF FISH

"In considering the subject it is well again to call to mind that the first essential necessary to maintain even fair fishing is this: All the work which it is possible for the State and national hatcheries to do by way of planting the waters should be supplemented by all the fish which may come from natural reproduction, and it should be so provided by law that the fish have every opportunity to spawn unmolested."

"Experts have solved most of the problems connected with the business at the hatcheries; but the field of investigation to obtain the best results in planting game fish in wild waters appears to be still open, and theorists are constantly discussing this feature in publications devoted to the interests of sportsmen.

"Here, then, is where the chief problem now lies, and it should not be left to novices to decide. It is universally recognized as the one important difficulty to overcome, and yet, strange to say, a majority of our leading fish culturists seem to have given the matter little or no attention in the past. They have devoted their entire time to solving hatchery problems, and at last these have been reduced to such an exact science that the experienced culturist can now calculate in advance to a nicety his season's output and the total funds required for its development. . . . In the past it has been the custom of culturists to assume that their full duty was done when they had raised a large, healthy stock of fish for planting. But when we look for permanent results and benefits from their work, it is certain that their task was only half finished. In the future they must abandon the hatcheries to their trained subordinates and seek the streams, ponds and lakes, and there apply their talents."

Henry Chase.

Game Propagation and Protection in America, pp. 187–189; 1913.

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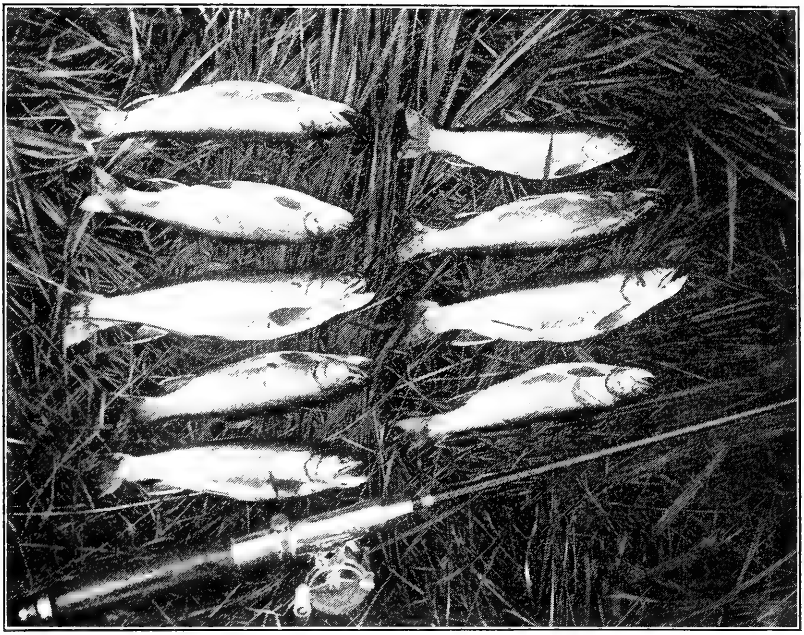

Fig. 20. Native brook trout.

Fig. 21. Introduced brown trout.

THE STATUS OF FISH CULTURE IN OUR INLAND PUBLIC WATERS, AND THE ROLE OF INVESTIGATION IN THE MAINTENANCE OF FISH RESOURCES

By Dr. William Converse Kendall

Ichthyologist, Roosevelt Wild Life Forest Experiment Station, Syracuse, New York

CONTENTS

INTRODUCTION

The original fish resources of the inland waters of North America were among the richest in all the world. The trouts, salmons, whitefishes, basses, perch, pikeperch, pikes and catfishes, are among the best food and game fishes known to man. This was a wonderful natural resource, which comprised not only a great variety of species but also vast numbers of individuals of the most desirable kinds of fish.

Our fishery resources have not been adequately appreciated by the public, even during the great wave of agitation for conservation led by Theodore Roosevelt, because through the lack of constructive leadership on the part of those most interested in fishery matters, the fish failed to receive their due share of attention.

The State of New York, bounded by the Atlantic Ocean, Lake Champlain, the St. Lawrence River, Lake Ontario and Lake Erie, contains in its inland waters about 125 native species of fish. It thus has one of the richest fish faunas possessed by any State in the Union, and yet this resource is slipping through our fingers, as it were, in the main because of indifference and ignorance of its value and of how to care for it intelligently.

The following resumé of the history of its original wealth and gradual decline, together with an estimate of its present status and future possibilities, may assist in orienting this resource among conservation problems. The emphasis on surveys and intensive investigations, it is hoped, will serve to discourage the customary indiscriminate planting, and the managing of this crop by promiscuous methods rather than on a basis of exact data, thoroughly correlated. Whether our inland fisheries will be stabilized or suffer further decline depends largely on which of these policies is emphasized henceforth.

The present paper sketches the broad outlines of some of the major problems involved in the fish cultural management of public waters, as they appear after years of study of this general field. The present drift of events seems to point very clearly to the conclusion that the main stronghold for game and fish in the future is to be found in the forests and waters of the non-agricultural and public lands. We thus anticipate an increasingly close relation among the problems of wild life and other phases of forestry in its modern sense.

ORIGINAL CONDITION OF THE INLAND FISHERIES

Former Abundance of Fish. That there was a great abundance of fish of various kinds in this country in early times is almost proverbial. Salmon, shad, alewives, striped bass and other kinds are said to have "swarmed" in all New England coastal rivers, and the inland waters "teemed" with brook trout, lake trout, and other choice fish. Concerning salmon, Goode ('03, p. 443) wrote: "Wonderful things are said about their abundance in colonial days. Every one has heard of the epicurean apprentices of Connecticut who would eat salmon no oftener than twice in the week." And he quotes from Peters' History of Connecticut, 1783: "The shad, bass and salmon more than half support the province. From the number of seines employed to catch the fish passing up the locks, one might be led to suppose that the whole must be stopped, yet in six months' time they return to the sea with such multitudes of young ones as to fill the Connecticut River for many days, and no finite being can number them." Such accounts, of which there are many, pertain to the coastal streams accessible to the fish from the sea, but the impression prevails that inland waters were likewise replete with fish. There may be a question as to what extent such a belief is justified.

Authentic accounts of the fish life of inland waters are rare. Some fifty years ago, Watson ('76), writing of salmon in Lake Champlain, says: "When the writer first became a resident of the district in 1824, many of the original settlers of the country were yet living, who were men of respectability and position, and of undoubted veracity. Their tales of the abundance of the salmon which prevailed at that time for their acceptance exercised the strongest faith in the truthfulness of the narrators. Coming from the unimpeachable sources they did, and corroborated by uniform traditions, and the current of universal testimony, by actual observers or participants of the incidents, there was no hesitation in receiving the statements as authentic and true. I have heard accounts from several of these individuals that when they immigrated many streams were so thronged by the salmon that it was unsafe, at particular seasons, to ride a spirited horse into them for the reason that the fish were so abundant and bold that they would fearlessly approach the horse and strike him with great force by the powerful muscular action of their bodies. It was often represented that it was a common pastime, as well as a most desirable means of obtaining food at that time, to drive a team into some of the shallow tributaries of the river, and from the wagon spear the salmon with pitchforks, and thus obtain in a few minutes all the fish needed for consumption. Many of the salmon taken in this primitive method would reach twenty pounds in weight."

The same author cites records of 1776 and 1777, which indicate that a pioneer in the Champlain basin had "complimented the American Army with 1,500 salmon in one year." Another incident, related by "so intelligent and reliable authority" that it corroborated the "almost incredible traditions of the former copious prevalence of the salmon in these waters," was to the effect that about the year 1800 or possibly a year or two earlier, as he was fording the Little Au Sable, a small shallow stream, near its mouth, the passage of his wagon was largely impeded by the throng of salmon which was in the stream, and he readily caught and threw upon the bank all he wished to take. Another account was that early in the past century five hundred salmon were taken in a single afternoon from the River Boquet, a tributary of the lake. Still another authentic account was that of 1,500 pounds of salmon having been taken by a single haul of the seine, near Port Kendall in the year 1823. These facts, the author thought to be "sufficient to sustain the proposition that the waters and the tributaries of Lake Champlain were teeming at a former epoch with salmon to an extraordinary, if not unexampled, extent." It is further stated that in 1838 one man caught 50 or 60 salmon in the Ausable River, where no salmon had been seen for

15 years. This appears to indicate that the salmon had ceased to "abound" in Lake Champlain as early as 1823, although more or less sporadic occurrences were afterwards reported. In his History of Vermont, the Rev. Zadock Thompson ('42), says of the salmon: "Only straggling individuals are now met with in Lake Champlain. I have heard of only one being taken here during the past summer, and that I did not see."

Salmon used to occur in Lake Ontario and frequented streams in New York and Ontario for spawning. In New York the most important stream appears to have been Salmon River, but they also ran up the Little Salmon and Oswego Rivers, and Little Sandy and Fish Creeks. With a view of the possible restoration of Salmon River as a spawning place for salmon, the United States Fish Commission instituted inquiries in that region in 1894. The oldest inhabitant interviewed was 90 years old. He stated that he moved to the locality in 1808 and remembered the rivers as far back as 1810. According to him salmon plentifully ascended the river to spawn, until the first dam was built in 1838. Another aged resident had speared and seined salmon for 70 years, and still another had fished there since 1835. Others had known the river and fished for salmon from 1850. Concerning the early abundance of salmon the following statements were elicited from those interviewed: Salmon were always plentiful until prevented from ascending the river by dams, or until about 1840. One man had known of 300 salmon being taken by a skiff in a single night. Another had seen 106 salmon taken in one haul of the seine. Notwithstanding the impeded ascent of the salmon, the river continued to be productive below the dam for a number of years. About 1850 it was said that an average night's catch was about 20 to 50 salmon to a boat, and that about 50 or 60 men were engaged in fishing for them.

In 1860, it was stated than 2 men in a skiff would get 30 salmon in a night and that 9 men, between Selkirk and Pulaski, made a partial living by salmon fishing. In 1868, a dozen salmon to a skiff in a night was considered a good catch, and in later years one persistent fisherman succeeded in catching 1 to 12 salmon in a season, although it appears that about 1880 from 60 to 100 salmon were taken in a day by gillnets, near the mouth of the river.

The foregoing indicated very little as concerns the actual abundance of salmon in the earlier days. That there was a decrease is manifest. The unknown factors are too many for definite computations. The duration of the fishing period may be approximately ascertained, but the number of days of actual fishing in that period is not known. The number of fishermen also would affect the computation. When the one man got 300 salmon in one night's fishing, how many other fishermen were there and how many fish did they get? By taking the stated average quantity of fish to a boat in a night, the stated number of fishermen at the same time, and assuming when the average was maintained, a result is obtainable which may or may not more or less definitely indicate how numerous the fish may have been. For example, in 1850, an average night's catch to a skiff was, say, 20 salmon. It was stated that there were 50 or 60 fishermen on the river at that time. It is not known whether they were individual operators, not counting assistants, or whether they represent the total number of men concerned. Inasmuch as two men operated a skiff, let it be assumed that there were 25 boats fishing. This appears reasonable as one man said he had seen 20 boats operating at one time. Then assuming that the average was maintained for 10 nights only, the total catch would have been 5,000 fish.

Now it was stated that 10 years later (1860) 2 men in a skiff would get 30 salmon in a night; and that 9 men between Selkirk and Pulaski made a partial living by salmon fishing. It is possible that there were 9 independent operators, each representing a skiff, so their catch each night would amount to 270 fish, and in 10 nights to 2,700 fish. This is more than half the amount taken in the previous instance, which might be accounted for by the increased average per skiff due to the decrease in number of fishermen.

The foregoing figures prove nothing more than the fact that the quantity of fish caught was in proportion to the number of men fishing. The more fishermen there were, the fewer fish to a skiff were caught; and, therefore, the presumptive evidence that the number of salmon present in those respective seasons could not have greatly exceeded the number caught. In the first instance possibly, but not probably, the total quantity caught was double the quantity computed, so it might be said that possibly the season's run was somewhat more than 10,000 fish, inasmuch as some must have escaped capture and bred somewhere to provide the runs of subsequent seasons. It would hardly seem probable that 10,000 fish were caught in any one season, unless there was a waste of fish. There was evidently a comparatively rapid decline. The market was limited and that the quanity of fish was less than the demand is indicated by the price per pound received, which was 12.5 to 20 cents in 1855, and 15 to 20 cents in 1860. In this connection it is interesting to note that in the very early history of the locality, salmon were bartered in the neighborhood, one pound and sometimes two pounds of salmon being exchanged for one pound of pork. In 1812, it is said, salmon brought 2 cents a pound; in 1820 the price was from 4 to 6 cents; in 1840, from 5 to 6 cents; in 1855, from 12.5 to 20 cents; in 1860, in Syracuse and Utica, 15 to 25 cents per pound.

In this country the salmon was always a food fish and apparently seldom, if ever, caught by angling methods. But from very early days the brook trout was a game fish as well as a food fish, and was sought by anglers, both young and old.

The older of us can remember the stories told by our grandfathers concerning the abundance of trout in the streams and lakes, and how they used to make periodical trips each fall to certain waters to catch trout, which were salted for winter use, or how they caught them through the ice in winter. A single story will serve as an illustration. One man (Rich, '83), all his life familiar with the Rangeley

Lakes region in Maine and long before it became widely known to anglers, wrote in an article in a sportsman's journal as follows: "Every brook, every stream, and every pond and lake was literally full of them. Of course, there were proper times to fish at certain places; for instance, at places where ample quantities could be taken at one time, none could be had at another time. I have seen the Cambridge River at the foot of Umbagog so crowded with trout rushing up stream that you could almost walk across it on the backs of the fish (if this is a fish story, it is an actual fact). And again in the fall of the year great schools would rush into the mouths of rivers and coves near their spawning grounds, so as to fairly blacken the water, and they were hungry.

"At the first freezing over of the lakes and rivers, at the mouths of small brooks and around certain stony banks in the lakes, and near late spawning grounds, hundreds of pounds could be taken in a day, and the hunters were pretty sure to improve these opportunities."

In another place, the same writer graphically described the first run of trout in the Kennebago River in 1884, where, he said, from the last of September to the freezing of the river in November, the trout resorted to spawn. He wrote that on September 22, having been attracted by the splashing of the water, sounding "like a drove of moose wading in the river," he saw a large school of trout, many of which were of large size, jumping out of the water and going through various maneuvers as they made their way up the river. They continued to run in large schools until all the spawning beds above along the river were fully occupied. He says that the number of trout running up the river could not be estimated but that in the small space of about 5 rods the spawn takers secured 500 trout from October 1 to 12.

The Rev. Zadock Thompson, in his history of Vermont, previously referred to, gave a very interesting account of the brook trout in Vermont, from which the following is quoted: "The brook trout is more generally diffused over the State than any other species of fish, there being scarcely a brook or rill of clear water descending from our hills and mountains in which it is not found. When the country was new they also abounded in larger streams, where they often grew to the weight of 2 or 3 pounds. But they have been diminished by the causes already mentioned and have been sought after with such eagerness as the most delicious article of food of the fish kind that they are now seldom taken in our streams exceeding half a pound in weight, and much the greater number of them weigh less than a quarter of a pound. In many of the ponds they are still taken of a larger size, but their flavor is thought to be less delicious than those taken in running water, especially in ponds with muddy bottoms.

"The trout is usually taken with the hook, and the bait universally used is the red earthworm, everywhere known by the name angle worm. Fishing for trout is a favorite and common amusement, and parties frequently go 15 or 20 miles for the sake of indulging in it."

The foregoing are but few of many examples indicating conditions of the fisheries before and after interference by the white man, and show to some extent upon what sort of evidence the traditions concerning extraordinary abundance of the fish were based. That every body of water was originally replete, to its biological capacity, with fish for which the waters were suited and to which they had access is in accordance with biological laws. It is undoubtedly true that fish have been observed in great numbers in streams accessible from the sea, so numerous in fact that it would almost seem that one could walk across on their backs, but how many fish actually composed such an aggregate is another matter. And when limited inland waters are considered it is still another matter. When the fisherman got 1,500 pounds of salmon at one haul of the seine in Lake Champlain, at first thought it may seem to have been a remarkable catch. But if those fish had each weighed 15 pounds, which has been stated to be the average, only about 100 fish were caught. How many fish could have been taken in subsequent hauls throughout the season? The fact that it was recorded as remarkable indicates also that it was unusual even in those early days. It is not stated whether or not the 1,500 fish with which the American Army was "complimented" in one year in 1776 or 1777, were all that were caught. It would appear that probably there were not many, if any, more fishermen in the region at that time. If there were, the question arises as to their success in the salmon fishery.

After all, the point is that whatever the number of salmon in former years, there are no salmon in those places today.

Depletion of Fisheries. In the olden days, it has been said, the salmon was a food fish rather than a sportsman's fish. So, also, with many other fishes which are now scarce. It is that fact that has led to the scarcity of many species which are now esteemed alike for their food and game qualities.

According to traditions, inhabitants of the neighborhood of waters which "teemed" with fish, captured them by the wholesale. The fish were taken primarily for food, usually for home consumption, but sometimes for the market. But those which were not disposed of in those ways were frequently fed to hogs or used for fertilizer. Those inhabitants usually did their fishing at times when the fish could be most easily caught in the greatest numbers. Accordingly the principal fishing operations were at or near the spawning time, when the fish were often wastefully slaughtered. Excessive and untimely fishing were not the only factors concerned in the depletion of fish in lakes and streams. In the old days one of the most potent of other factors was the erection of dams in the streams with no provision for the ascent of fish. Fish which went down stream could not get back. Thus many species were shut out from their breeding places, and unless other suitable places were found, the fish died out. If suitable spawning places at first existed below sawmill dams, ere long the waters were choked with sawdust and other mill waste. The destruction of the forests and the drainage of the lakes, ponds and swamps in many places, have all had a most unfavorable influence upon fish.

Concurrently with an increase of population the decrease in quantity of fish was hastened. At first, sportsman-anglers were few, and as a rule they sought only game fishes of highest repute, in which category only a comparatively few species were admitted. Most of these were members of the salmon family. Usually salmon fishing was restricted to Canada as, for the most part, New England streams had been depleted, not wholly on account of excessive fishing, however, but also owing to obstructions to the ascent of salmon.

Finally there came a time when the class of game fishes had to be enlarged by the admission of other species, and the old aristocrats of the class became less valuable as commercial food products and more valuable as objects of sport. Accordingly, when given any conservative attention at all, one after another the fish were removed from the commercial food fish class, and were legislated for in behalf of the angler. So today there is scarcely a fish, that will take a baited hook, which is not somewhere, by some angler, regarded as a game fish. Furthermore, many of those species, formerly regarded as coarse fishes and neglected by the commercial or market fishermen, finally became of economic importance, and they, too, began to decline.

Early Measures for Restoration. In some localities declines became quite noticeable in the early history of the fisheries, and various measures for protection of the fish and restoration of the fisheries were enacted by state legislatures. At first, legislative acts concerned food fishes only with little or no consideration of the angler's interests; but after a while two interests had to be recognized, that of the commercial fisherman now being paramount and that of the angler secondary. The division of interests gave rise to problems of where to draw the line between the groups which should receive special legislation as commercial or food fishes and game fishes respectively. Certain fishes had to be admitted to both categories, although the interests of the commercial fishermen and the anglers sometimes conflicted. The locality finally often determined the class to which certain fishes should belong, giving rise to special legislation with its attendant advantages and disadvantages. So fishes which in one locality became classed as predominantly commercial fishes, in other places were classed as game fishes only, and their sale in the markets was restricted or absolutely forbidden.

As has been said, while at first protective and remedial legislative measures were directed toward the commercial fishes, later special game fish legislation was enacted and various fishes were given game fish legislative attention. These fish laws necessarily varied in different states and sections of the country, and almost everywhere appear to have failed of their purpose.

The unsatisfactory results of protective and restorative fish and fishery legislation were so marked that the introduction of fish culture or "artificial propagation" was hailed with unbounded enthusiasm. To those persons most concerned — the State Commissioners, fishermen and anglers — artifical propagation was the "Sesame" which was to open the gates through which the sea, rivers, lakes and streams were to be rehabilitated. In 1872, one enthusiast said: "Every stream on the Atlantic seaboard can be so filled with shad that they will sell at all the fisheries at one cent a pound within the next ten years." Another predicted that "the time is not distant, if we may be allowed to forecast the future, when every available river or stream of the continent will be as carefully cultivated as ever our soil was, for the augmentation of this great source of food."

Dr. Theodatus Garlick of Cleveland, Ohio, is generally credited with the first successful attempt at artificial propagation in the United States. In 1857 he published "A Treatise on the Artificial Propagation of Certain Kinds of Fish, with Descriptions and Habits of Such Kinds as are the Most Suitable for Pisciculture." While in his preface Dr. Garlick states that he would "endeavor to present the reader with not only a complete description of such American fishes as are best suited by their qualities and habits for artificial propagation and culture, but also the best methods of propagating and rearing them; together with the most appropriate kinds of waters for each kind described," his most signal success was with the "brook trout."

Concerning this first attempt Dr. Garlick wrote that early in the spring of 1853, Prof. H. A. Ackley and he decided to make brook trout the subject of their first experiment in artifical breeding. During the following years others went into trout breeding as private ventures. Some of the most noted of these fish cultural pioneers were Thaddeus Norris, Seth Green and Livingston Stone. In the early sixties Maine, New Hampshire and Massachusetts established State Fish and Game Commissions, which gave the marine anadromous fishes, such as salmon and shad, the first propagative and legislative attention, but incidentally extended their stocking activities to inland waters and to other fishes. Other states soon followed the example set by these New England States. Private enterprises, however, continued to exist in some of the eastern states. These latter were particularly interested in the propagation and sale of brook trout. There were numerous trout farms in New York, New Jersey and the New England States, which found a lucrative business in the sale of trout eggs, young fish for the purpose of supplying other ponds, and in furnishing hotels with full grown trout, which were sold for a comparatively high price.

The combined interests of private concerns and state commissions led to the formation of the American Fish Cultural Society, now known as the American Fisheries Society. This Society is credited with being one of the agencies instrumental in bringing about the establishment of the Federal Commission of Fish and Fisheries, now the Bureau of Fisheries, U. S. Department of Commerce.

The decline of the sea and river fisheries was the first object of inquiry by the United States Commission. Subsequently propagation of game fish for inland waters constituted a considerable part of the function of the Commission, and still forms an important division of the Bureau. Federal fish hatcheries and fish cultural stations of one kind or another have been established in almost every state of the Union, and the states have their own hatcheries, sometimes as many as a dozen or more in one state. Millions upon millions of fish eggs have been hatched and the young distributed far and wide in waters of this country and foreign lands. Fish of various kinds have been imported from Europe and planted in the waters of this country, and thousands upon thousands of dollars have been expended in these operations. The results attained are indicated by the present conditions. (For a general account of the history and policies of the U. S. Bureau of Fisheries reference should be made to H. M. Smith, '10.)

PRESENT CONDITION OF THE INLAND FISHERIES

To the fisherman and angler there appears to be something radically wrong as concerns the food and game fishes of the inland waters. Notwithstanding the many years of extensive and intensive effort and great outlay of money, the expected results have not been attained. Shad have not been "reduced to one cent a pound." Atlantic salmon are extinct in nearly all the rivers of New England, and it is only in the remote and silent places that the brook trout can be found, naturally, in their former abundance. Even the extensive importations of extra-limital fishes have failed to supply the deficiencies except in scattered localities; only a few, if any, rivers, streams, lakes or ponds have been permanently restored or stocked to a self-maintaining point. A single example will serve to illustrate the present situation, as similar conditions obtain with other species.

Let us take the case of the "rainbow trout" which has been propagated and distributed for more than 40 years in the eastern states. There are but few localities where the successful results appear to be anywhere nearly commensurate with the expenditure of money and effort. In fact in the eastern states there are but few localities where the reports indicate that attempts to acclimate the fish have been at all successful. In the 40 years from 1880 to 1919, inclusive, the United States Fish Commission or Bureau of Fisheries has delivered to state fish commissions over 6,000,000 eggs and distributed more than 21,000,000 young "rainbow trout" in the states east of the Mississippi River. But the old problem still exists. What is the answer? To this question the law of cause and effect applies, as in all problems of like nature.

Causes of Deterioration. Inland fish culture developed, through the need of restoring depleted river fisheries, into restocking inland lakes and streams. In a commendable effort to improve the angling, in many cases, zeal and enthusiasm seem to have outweighed judgment and forethought, resulting in the idea that the assembling in large quantities of every kind of available game fish in a body of water was a most desirable consummation. So, while most estimable species native to the waters were neglected (figure 20), exotic species (figure 21) were brought from other states, and even from foreign countries. It was a long standing practice, which to some extent still prevails, to exchange fish locally plentiful in one state for fish from other states and foreign regions.

These efforts to meet the rising demand were made without knowledge or consideration of the existing conditions of the waters or the possible effects of the introduction upon either the native or introduced fishes. In this respect early fish cultural distribution was of the nature of a venture rather than a rational procedure or experiment. But it was a natural and unavoidable concomitant of the distribution of non-indigenous forms, the nature and requirements of which the fish culturist of those days was necessarily ignorant. The trouble lay in not realizing that new factors were likely to disturb normal conditions, and that the way to regulate conditions already disturbed was to restore as nearly as possible original or normal conditions.

Indiscriminate planting of fish in the past and even today is the cause of much of the present unsatisfactory situation. Instead of trying to maintain a supply of fish in those waters to which the fish were known to be adapted and in which they formerly thrived, the fish have been scattered broadcast into large lakes and little ponds, near and remote, without regard to the habits or physiological requirements of the fish, and often to the detriment of the fish native to the waters into which the transfers were made.

As an example, the landlocked salmon of Maine, naturally occurring in only this one state, may be mentioned. It was one of the earliest fish to be propagated and distributed. In that State, too, the brook trout existed in untold numbers, and in some waters attained a very large size,— trout of 10 and 12 pounds being recorded. For years a chain of lakes in the northwestern part of the State was famous for its huge trout and renowned for its fishing.

The State Commission proceeded, as they thought, to add to the piscatorial attraction of the lakes in question. The first act was to plant sea salmon and later to transfer landlocked salmon from their native waters to those lakes. Not only were the salmon planted in the large lakes, but also in almost every little pond in the vicinity. This also holds true of most of the other principal lakes of the State. Even though it was regarded as possible and desirable to plant salmon in the larger lakes, it is hard to conceive of reasons why it seemed necessary to introduce them into every small accessible lake and pond already supplied with brook trout.

In the larger lakes of the particular chain mentioned the salmon has thrived, but at the expense of the original inhabitants. In the smaller ponds the only results obtained have been the decrease of trout and the capture of a few salmon now and then, which had grown up from the original plant. They did not thrive and reproduce because the conditions made it impossible.

A good example of the disastrous effects of indiscriminate fish cultural operations is that of a small pond in Maine, which was originally inhabited by a species of trout found in but two or three lakes elsewhere and in no other place in the State. As soon as it was discovered, it received fish cultural attention. Every season these fish were seined, stripped of eggs, hatched and distributed in other waters, until the trout became so scarce in the pond that it was fish-culturally unprofitable to operate any longer. Of all the young of this fish planted in other waters not one has survived, for the reason that no one of the lakes in which it was planted was suited to the physiological requirements of the species. Instead of endeavoring to increase and maintain this rare species in its one known favorable habitat in the State, landlocked salmon, steelhead trout, Scotch sea trout, and various other species were planted in the little lake,—which seems strange in view of the fact that not far distant was a comparatively large lake which was one of the four localities in the State where landlocked salmon naturally occurred. Of all the species planted in that little pond, not one now remains.

Another extreme example of this kind may be cited. Sunapee Lake, in New Hampshire, formerly was noted for its numerous and large trout. This fact led the Commissioners to try to make it still more attractive. Prior to fish cultural introductions, which began with landlocked salmon in 1867, so far as records show, the list of native fishes of the lake comprised an even dozen species. There were hornpout, common sucker, four species of minnows and chubs, two species of chars or so-called trout, eel, pickerel, sunfish and perch. From 1867 to 1909, fourteen other species had been introduced; namely, landlocked salmon, blackbass, smelt, whitefish, blueback trout, round whitefish, Loch Leven trout, brown trout, rainbow trout, chinook salmon, grayling, silver salmon, pike, perch and lake trout, although the last named was probably by accident. Of these the whitefish, pike, perch, blueback trout, Loch Leven trout, rainbow trout, silver salmon and grayling have never been reported, and only one or two brown trout have been observed. Of the introduced species only the blackbass, smelt, landlocked salmon, and chinook salmon ever manifested themselves in sufficient numbers to produce any appreciable effect on the conditions of the lake. The pickerel decreased in numbers, the perch became almost or practically extinct, cyprinoids were far scarcer than in former years, and the landlocked salmon had greatly decreased in number, when the chinook was introduced. The second species of char or "trout" was not discovered until 1885 or about that year. It had not been known anywhere prior to that time, but had evidently always existed in the lake, although unrecognized as different from the brook trout. It was subsequently described as a new species and at once became famous. It was then given the usual attention by the fish culturists and distributed far and wide in other waters with no positive results.

Here was a lake, which, according to tradition, at one time abounded in trout, the only known or recognized salmonids of those waters. In early times the trout were killed in their spawning beds, caught through the ice, and netted in the lake. Necessarily such intensive procedure resulted in depletion. The very first step to repopulate the lake was not by propagation and planting of trout, but by the introduction of landlocked salmon. One year later smallmouth blackbass were introduced. Two years after the first plant of the latter fish smelt were planted. So far as the salmon were concerned this was a wise provision. In the State Fish Commissioner's reports no reference is made to planting of trout in this lake until twelve years after the planting of the first landlocked salmon, but up to that time over 16,000 salmon had been planted. But in the subsequent 30 years, over 1,000,000 young trout, and over 700,000 landlocked salmon were planted.

Up to about 1895 salmon were reported to be abundant and large, but in the following ten years they greatly declined in number and fell off somewhat in average size. In 1904 the chinook or king salmon of Columbia River was introduced and some were planted nearly every subsequent year. The first catch of this species was made two years later. They were caught each year subsequently in increasing numbers, and it was estimated that in 1910 from 400 to 500 were caught — ranging from a little over 2 to nearly 17 pounds. Large catches were reported in 1912 and 1913, but later they began to fall off in the number of fish taken, so that in 1917 the situation was as follows,— to quote the former State Fish Culturist of New York, who said a former New Hampshire Commissioner thus wrote him: "Fishing all gone to hell, not a salmon this spring; the chinooks were good for a time, but do not reproduce and have all been caught out. They have dumped lots of fish in the lake, but they seem to do us no good."

In this lake the decline of landlocked salmon was attributable to lack of suitable spawning places, and failure to plant more fish for a number of years.

Concerning the chinook salmon in Sunapee Lake, the present writer once had occasion to state that to his mind at least, a permanent self-sustaining stock of chinook salmon in that lake was unattainable, and, unless the existing stock was self-sustaining, it was a waste of time, money and fish to continue planting it, for the day would surely come when the supply of eggs from the west must fail; that if this fish has been maintained in the lake in the number then present, the disappearance of the fishes upon which it feeds must be hastened, and when the chinook stock also was gone, the lake would be worse off than ever before, and there would be some who would call for recommendations as to how to improve the fishing (Kendall, '13).

A letter recently received (July, 1922) from the Commissioner of New Hampshire says: "Chinook salmon have had their ups and downs in Sunapee, as in most lakes in the East. We have had several seasons at different times when the fishing was excellent and great numbers were taken. It was possible to estimate their age with considerable accuracy as in the different years the catches were practically about the same age, and it is pretty clear that none of them last over five years."

The experience with the chinook salmon in Massachusetts has been similar to that of Sunapee Lake, and substantiates the foregoing prediction by the present writer. From 1913 to 1920 inclusive, 420,215 young chinook salmon had been planted in fifteen ponds and lakes in the State. The report of the director of the Division of Fisheries and Game of that State for 1920 (W. C. Adams, '20), says: "The attempt to establish the Pacific salmon in Massachusetts waters was, at the best, an experiment, and, while in the matter of growth some of the fish planted in Long Pond, Plymouth, exceeded expectations, there was insufficient evidence that they reproduced. Indeed, the probability that they would fail to do so was always recognized, and that constant stocking would be the price of whatever salmon fishing our waters might afford. Thus as each fishing season came around the results were watched with the keenest interest, and more so than ever in 1920, because the catch of 1919 had fallen off materially from that of the previous year. The salmon fishing in Long Pond failed utterly in 1920."

Long Pond had been stocked with 24,000 young salmon in the years 1914 to 1917 inclusive, and the following catches were subsequently made: In 1917, about 100 salmon, the largest weighing 7 pounds; in 1918, probably 350, running from 2 to 9 pounds, with 2 or 3 at 12 pounds; in 1919, about 800, but small sized, from 2 to 4 pounds; and in 1920, very few, the largest 4 pounds. However, the report for 1921 states that in several ponds an occasional specimen was taken, and in Long Pond upwards of 500 fish were caught during the entire open season.

It appears that in most of the ponds that had been stocked no salmon at all had ever been taken. In three of the ponds a very few specimens had been caught. Lake Quinsigamond, which was the first Massachusetts lake to be stocked and which had received 89,250 young fish during the years 1913 to 1917 inclusive, is said to have yielded possibly 70 fish in the third season, after which they disappeared.

In 1919 the planting of chinook salmon was abandoned by the Massachusetts Commission, as it was not possible to obtain a satisfactory supply of salmon eggs for the hatching work of 1920. Oregon advised that no eggs could be expected; in California egg-taking was the smallest on record; Washington could promise only 200,000 as against 600,000 and upwards in other years.

So it appears that the chinook salmon expectations in the eastern inland waters have failed, as most such random "experiments" have failed and always will fail; but the tendency to indulge in them still continues.

In the summer of 1921 a notice appeared in a Portland, Maine, paper to the effect that the Governor was arranging to have Sebago Lake stocked with Canadian sea salmon, "in order that there always may be good fishing in Sebago Lake." The notice stated that if the "experiment" was successful Canadian salmon would be placed in other lakes in Maine.

Sebago Lake is one of the four original landlocked salmon lakes, in which formerly the fish attained the largest size of any waters. The State maintains a hatchery on one of the affluents of the lake, and collects the landlocked salmon eggs from fish taken in that stream. Why, then, was it deemed necessary to resort to Canadian sea salmon in order to maintain good fishing in the lake? One of the reasons is that the Sebago salmon have for years been a source of supply for eggs with which to stock other waters, even small ponds in various parts of the State. If even the fish planted in small ponds had been restored to Sebago Lake, the effect upon the stock would have been appreciable. There is scarcely a lake or pond in Maine into which landlocked salmon have not been introduced. Landlocked salmon have been shipped promiscuously over the country, to the Pacific Coast, Europe and the South Pacific, and the "experiments" have so reduced the stock at Grand Lake Stream and Green Lake (both original salmon lakes) that now not enough eggs can be obtained there to maintain a stock and meet the demands for distribution. For additional eggs it has been necessary to draw upon the fish of artificially stocked lakes, and they are becoming reduced, if reports are true.

Titcomb remarks that in Lake George, New York (Titcomb, '22, p. 77), the experience with landlocked salmon is as follows: "In response to a public demand, landlocked salmon have been planted annually in the lake; 15,000 or 20,000 and sometimes more have been put in the lake or in the tributary streams for a long period of years. Reports indicate that the results have been unsatisfactory, an average of about ten mature salmon being caught from the lake each year."

It would appear that here is an example of long continued "experiment" with the usual results. Apparently no effort has been made to ascertain if Lake George is suited in every way to the salmon; whether there are suitable spawning beds and plenty of suitable food for all ages of fish from the time they are planted until they attain maturity. These are some of the conditions that should be first ascertained before further attempts to stock the lake with salmon are made, whether the salmon to be planted are fry, yearlings or older.

The conditions to which reference has been made are not restricted to any one state. They are nationwide, and it may be added worldwide in some respects. To a great extent all are in the old groove of error. The wonder is that only a few of the more intelligent have recognized the error and have made any effort to profit by past mistakes, and that the majority are ever ready and willing to subordinate reason to personal expediency or selfish ends. Man has ever been an insensate, irrational, time-serving destroyer. Many of our fish and game and conservation officials have had the public interest at heart, but have been handicapped by the political factor, which, controlled by more or less powerful individual and organized interests, was, and still is, a factor tending to instability.

The results of such conditions are manifested in some of the present problems of conservation, and the author is here constrained to express his firm conviction that these problems will not be solved or conditions greatly improved until a way is found to harmonize the individual and organized interests with the public interests, as they pertain to fish and game. And, furthermore, unless harmony is attained it will not be many years before there will be no fish and game interests to harmonize or fish and game to conserve. And, again, if he may be pardoned for referring derogatively to the sacred institution of political favor, the author is compelled to say that no harmony can be attained, no conservation consummated, until that factor is eliminated.

Remedies for Present Conditions; Investigations. In his annual report for 1921, W. C. Adams, of the Massachusetts Conservation Commission, referring to the early depletion of fish and game, says: "It is useless to inveigh against the profligacy with which this great wealth has been squandered in the past, save for the lessons that may be drawn for present and future guidance. While we take pride in contemplating the amount of wild life still remaining in our comparatively small State, such pride must be fully tempered by the realization that even we, who have had and still possess one of the most enlightened public opinions on this continent, have wasted our substance in riotous living."

This great wealth which has been "wasted in riotous living" can never be restored, but what there is left can be so invested and controlled that it will not grow less, and even perhaps increase, providing *we learn our lesson,* not only from the "profligacy" of our pioneer ancestors, but from the results of defective fish cultural policies and practices of the last half century, which to no small extent continue to this day.

W. C. Adams previously wrote ('20) that the greatest concern of those who are studying the relation between the wild life of any given state and the increasing drains on it, through the taking in each year, is the fact that there is probably no species of game bird or fish which is more than holding its own. The annual production of the bird farms and fish hatcheries is not in proportion to the increasing sportsmen and fishermen who take to the fields, and very little or no margin is left for the inroads on the stock due to unfavorable breeding seasons, forest fires, cutting of the covers, severe winters, and ravages of vermin. While Adams referred particularly to game birds, the principle is applicable to the game fish situation, even to include unfavorable breeding seasons, forest fires and cutting of the covers.

The previously discussed perpetuation of erroneous practices and mistaken policies of the past, must be recognized and modified. The remedial policies of the past may be likened to the administration of a narcotic drug to alleviate pain, the cause of which was unknown. It developed into a habit which is now difficult to break. In many instances its continuance or cessation signifies the same thing — the death of the victim. The only hope offered is in an effort directed toward the elimination of the drug from the system and the restoration of its normal functions, so far as normal conditions can be restored.

The problem is how to eliminate the drug from the system and how to restore normal conditions. A former Federal Commissioner of Fish and Fisheries said: "The fishery problems of fresh water are undoubtedly simpler than those of the seas, but they are certainly less directly approachable than the problems of agriculture which have met their solutions. It is not surprising therefore, that throughout the country in matters of fish culture, there is yet too little endeavor to find real causes or to apply appropriate remedies."

To continue the medical figure of speech, as previously suggested, the early and to some extent late administration of remedies were in the form of "shot-gun prescriptions," without knowledge of the anatomy and physiological processes of the patient, — or even the cause of the affection or the therapeutic properties of the remedies employed.

In other words, in the past, millions upon millions of fish have been planted in lakes and streams of the United States without any scientific investigation whatever for the purpose of determining whether the waters were suitable for the fish which were proposed to be planted in them, or whether the fish were desirable for those waters. The situation is that hundreds of thousands of dollars have been spent and millions of fish have been wasted without results of practical value having been obtained.

To quote again from W. C. Adams of Massachusetts: "It is elementary that the largest amount of wild life will be found in the area (whether land or water) that is most adapted to it, and where food and protection (in its fullest sense) are present to the economic maximum. It is a fair assertion that there is no area of land or body of water in this Commonwealth today on which primeval conditions have been maintained or artificial conditions developed to the point where it can be said that that area is in such physical condition that it will maintain indefinitely its full quota of wild life. If this is true of certain areas whch have had special attention, then we are in a position to visualize what is the actual condition throughout the entire State, and how hopeless it is to expect great increase in the stock of wild life until conditions approximating the economic maximum can be created."

This situation is not peculiar to the Commonwealth of Massachusetts. It is the prevailing problem almost everywhere, and the question appears to be how to establish a balance between game fishes and their food supply and maintain it with satisfactory fishing.

About thirty years ago, concerning the stocking of streams, Dr. Barton W. Evermann ('94) indicated that "to do this work intelligently it must be based upon a knowledge of the natural conditions under which each species thrives, which of the factors in its environment are essential, which only desirable, which negative, and which detrimental to the best life and growth of the fish. . . . This of course means careful observation and study of all the physical, chemical and biological features of each stream, for these are the conditions, forces or elements which together constitute the fish environment, and which determine the presence, abundance, distribution, and condition of the various kinds of fishes found in each particular stream or lake."

Dr. Evermann further pointed out that the temperature and chemical character of the water, the volume or size of the stream or lake, the character of the shores and bottom, and the surrounding country, all must be ascertained. Not only these facts, but also the life histories of the fishes themselves, what other species of fish and what other animals and plants are found with them, and their abundance and habits, should be learned. Then after the determination of these facts of the fishes' environment, a second and vastly more difficult series of investigation must be taken up, namely the bearing of these facts upon the life of the fish. "The whole subject of the relation of the various animal and plant forms found in our waters, their action and reaction upon each other, and their relation to the physical as distinguished from their biological environment is the subject which is demanding investigation and upon which investigation must depend all important advances in fish culture and fishery legislation."

All this means that in undisturbed nature, there is an approximate balance or counterpoise of interrelations of the organisms composing the animal and plant life of every body of water, subject to automatic regulations. Where there is an interference, the balance is tilted one way or the other in direct proportion to the amount of interference. Every body of water, large or small, has a limit to the amount of life it can support, and any interference that produces an excess of that amount, or any part of it, proportionately deranges the balance. An undue reduction of any part of that life may result in an over-increase of some other parts, with a final result that these, or still other parts may be reduced. In other words, the organisms are not only interrelated but are more or less interdependent, and it cannot be foretold how far-reaching and disastrous the effects of the destruction of any one of them might be.

While natural phenomena may affect the balance, the principal factor of interference is man. Apparently nature did not take man into consideration when she adjusted the balance, and for the reason that his influence has been mainly destructive, in many instances the conditions have been so upset that he has felt called upon to effect a readjustment, which he has endeavored to accomplish by means of fish culture. In his efforts in this direction he has not always been guided by sound judgment, as has been shown, and too often the consequences have been that sooner or later the conditions have become worse than they were before.

For example, there have been waters in which pike and other fishes have lived in reciprocal counterpoise from time immemorial, notwithstanding the condemned "characteristic voracity of the pike." Supposing that at some particular time the pike had been rendered less voracious, the tendency then would have been toward an undue increase of the natural objects of that voracity, which had probably been relatively as voracious on their own part in devouring the eggs and young of the pike. The increase of these forms might have resulted in the extermination of the pike, which would naturally have been reflected upon the other forms by depriving them of a part of their customary and requisite food supply, consisting of the eggs and young of the pike, and so have resulted in the decrease, deterioration, or extinction of these forms upon which the pike had exercised that quality, which has been generally regarded as superlatively bad.

This is a phenomenon that is usually manifested as a result of over-fishing, which amounts to the same thing as depriving the pike of its voracity, and similar to what happens when blackbass are introduced into pickerel ponds — of which there are many instances, but the cause of which has not been fully recognized. For instance, it has been recognized that blackbass have practically exterminated pickerel in certain waters, but why the blackbass afterward deteriorated in size and number did not seem explainable. These facts may be equally applied to other fields and fishes, as respects their artificial distribution, and particularly to the members of the pike family itself, for it should be borne in mind that the reverse process of the foregoing is just as effective. If the pike should be rendered more voracious, or, what amounts to the same thing, unduly increased in number, it would signify that sooner or later the food supply would be depleted, with the result that the pike would be forced to depend more and more upon its own young and would finally figuratively swallow itself (Kendall, '17).

Let us consider a more specific but still somewhat hypothetical example. It is stated that the main dependence of lake trout in Lake George is the whitefish. Both fish are indigenous to the lake. They were both factors in the original balance to which reference was previously made. The original food supply of the original trout was therefore in equipoise with the trout. Apparently something has happened to upset that equipoise which is manifested in a decrease of size and number of lake trout. This should result in an increase in number of whitefish, if there were no other whitefish eaters in the lake. If this has happened the lake trout stocking limit depends upon the present amount of whitefish as food, other things being equal. The lake trout is said to have no competition for that food. The main subsistence of the whitefish is Entomostraca, for which there are several kinds of competitors, such as minnows and the young of other species of fish. An over-increase of competitors would decrease the food of the whitefish. A decrease of the whitefish food would be at the expense of the whitefish. An over-increase of competitors for the whitefish food would result from a decrease of those forms which maintained the balance by subsisting upon those competitors. "Pickerel" subsist largely upon minnows and to some extent upon the young of other fishes. Pickerel have become scarce in Lake George. Minnows should have increased in proportion. The minnows eating whitefish food deprive the whitefish in proportion to the increased amount eaten by minnows; the resulting decrease in the number of whitefish deprives the lake trout of food; and the lake trout deteriorate and become less numerous.

Whether probable or not, it is possible that the growing scarcity of pickerel in Lake George has been an additional factor to that of man in reducing and maintaining the reduction of the lake trout stock. An increase of other fishes, particularly those which subsist to any extent upon Entomostraca would have the same effect. Hence before recommending certain measures for the reduction of pickerel and rockbass, it would be well to first make sure of our grounds for such recommendations.

Dr. G. Brown Goode once said ('94): "Scientific research involves four processes: (1) observation; (2) the record of the results of observation; (3) the classification and assimilation of these results; (4) their interpretation, both for immediate use and as a guide for subsequent inquiry."

There have been many investigations of inland waters when observations were made and the results recorded; some in which the results have been classified and perhaps assimilated; but there have been but few, the results of which have been interpreted for immediate use or subsequent guidance.

In his recommendations concerning measures to improve the fishing in Lake George, Dr. J. G. Needham ('22) makes two major divisions: I. Measures immediately applicable, and II. Measures looking toward the future. Under the latter division he says: "Go out after more knowledge. Nothing else will serve as a basis of rational procedure. In all doubtful and difficult fish cultural practices substitute carefully planned studies for random observations and exact knowledge for hearsay. On every hand are problems of fish production with the limiting factors unknown. The cure for this condition is research."

In conclusion concerning certain suggestions, Dr. Needham said that he made them because it was perfectly clear to him that all success in husbandry is based on intimate knowledge of the natural history of plants and animals and of their relations to each other. "This knowledge," he said, "we must have for fishes before we can have completely successful fish culture."

Consult the dictionary of a few years ago and you will not find the word "ecology," but modern dictionaries define it somewhat as follows: "The branch of biology which deals with the mutual relations between organisms and their complete environment." The foregoing statements concerning the necessity for biological and physical investigations of waters simply signify ecological study. In recent years ecological studies have become quite the fashion with certain biologists and to some extent fishes have received such attention. But until recently such study has had little or no place in fish culture, although a few scientists and fish culturists have recognized its importance in that direction. Neither the United States nor any individual state has ever made a complete survey of any lake or stream. There have been a few surveys that have been carried on for a number of years and a very few comprehensive studies of lakes, but never one that could be said to be thorough.

As long ago as 1886, Dr. R. E. C. Stearns wrote that a knowledge of the character or peculiarities of the environment or native haunts of the species selected for transplanting has to be obtained, and preceding the distribution and planting of the young fish an inquiry and consideration of the factors or physical character of the region in which it is proposed to make the plant of fish should be made.

These investigations having been made, a comparison of the conditions of the original and proposed new environment is the key to intelligent fish cultural distribution. But such procedure has never been the practice except in a very general inadequate way. To quote again from Evermann ('94): "Most of the work which has been done so far [in lake and stream study] has been in the line of determining factors in each environment, rather than guessing at what the factors mean. Heretofore great harm has been done by guessing at the facts and also guessing at their meaning. We believe it much better to be content for the present with the observation and recording of the facts, and wait until more facts are in before interpreting their meaning."

Within certain limits this is sound reasoning. But in all the years since those words were uttered the principal effort has been directed toward the accumulation of facts. Numerous investigations have been made and an almost unwieldy accumulation of facts has been acquired, and until more recent years there has been scarcely any attempt to analyze facts and apply them in practice. The result has been that early ascertained facts have been consigned to garret files, if not destroyed, or those which have been published have been buried in reports which are not generally available and therefore are virtually lost. When, finally, there has been an awakening to the absolute necessity for solving certain problems, the facts have to be sought anew.

A few states have made a beginning along some such lines as the foregoing pages suggest. For a number of years the Massachusetts Commission has had a biologist on its staff, but his duties comprised all biological subjects on problems pertaining to the fisheries of both inland waters and the sea. With his report for the years 1912, 1913 and 1914, he submitted a special report upon preliminary investigations for the systematic stocking of inland waters, in which he said: "Unless a State Fish Commission has a definite working knowledge of the inland waters, as a basis for methods of distribution. indiscriminate stocking will eventually lead to considerable loss. Extensive hatchery production increases rather than decreases this error, which can be remedied only by a systematic method of stocking based on an accurate knowledge of the waters to be stocked."

Referring to preliminary surveys begun three years before, the report says: "This preliminary study by no means completes the problem. Succeeding it should come more careful and detailed work, designed to increase ultimately the supply of food and game fish by (1) a study of the food, growth, spawning and habits of the different species of fish inhabiting various waters; (2) the determination of the species best adapted to certain classes of waters by an experimental study of type waters. There are, therefore, two parts; first, the preliminary general work, consisting of an extensive biological survey of the waters in regard to their general conditions to form a guide for future stockings, and a classification of these streams and ponds into certain groups, according to the similarity of the natural environment; second, an intensive study of various type waters, representing the groups above mentioned, as regards the effects of the natural conditions upon fish life. In such bodies of water records of temperatures, amount of food (plankton) and general changes which concern the problem of fish life should be followed for a number of years. The work of these type waters should serve as a basis for interpreting the conditions in other waters of similar nature." (Public Doc. No. 25, 1916, p. 86.)

For a good many years physiographical and biological surveys of inland or fresh waters of various parts of the country have been made for one purpose or another by the United States Fish Commission, now the Bureau of Fisheries. With the establishment of the Fairport Biological Station in 1908 on the Mississippi River, the Bureau began a definite program of investigation of these inland waters (Coker, '16).

Also, from time to time, the zoological departments of some of the state universities and colleges, have cooperated with various state departments, or even individual professors have independently undertaken such work, and the results of their studies have been published. Thus in Illinois, Forbes, Kofoid, Richardson, Shelford and others; in Wisconsin, Birge, Marsh, Juday and Pearse; in Michigan, Reighard, Ward, Hankinson and others; and in Indiana, Eigenmann, Evermann, Scott and others, have given much attention to investigations of fresh water biology which have a direct or indirect bearing upon fish culture.

In New York State, Needham, his associates and students, Betten, Johannsen, Clemens and others, working originally through the State Entomologist's Office and the New York State College of Agriculture at Cornell University, have given much attention to life history studies of aquatic insects and to fresh water biology in general.

FISHERY INVESTIGATIONS AND SURVEYS IN NEW YORK STATE

In the East, the State of New York was one of the earliest if not the earliest to perceive the importance of fishery studies. The general investigations to which reference is made pertained mostly to lakes. In New York State it is interesting to note that nearly 30 years ago the President of the State Fisheries Commission delegated Superintendent Fred Mather, of the Cold Spring hatchery, and Bashford Dean, then assistant at Columbia College and tutor in biology in the College of the City of New York, to make an examination of the two principal bodies of fresh water on Long Island, and, accordingly very careful examinations of the physical and biological conditions of Lake Ronkonkoma and Great Pond, at Riverhead, were made (Mather and Dean, '95). According to Bean ('09) nine years later a brief examination of two other lakes were made. "An investigation of Long Pond about eighteen miles southeast of Potsdam was made August 10th, by direction of the Commissioner. This lake is about one mile long and one-fourth mile wide. It has been stocked with brook trout in large numbers and contains a great many trout, but is overrun with suckers, and chubs, which destroy the eggs of the trout, and make it difficult to carry on their culture.

"For some years Lake Salubria, located about one mile from Bath, has been stocked with rainbow trout, lake trout and other species. It has also received some pikeperch, and it is said to contain some bass and pickerel. No trout have been caught in the lake as far as known, and it is doubtful whether it is expedient to continue the attempt of making a trout lake of this body of water."

The first intensive study of lake biological conditions in New York State was undertaken by Birge and Juday, in 1910, when they were enabled to visit the "Finger Lakes," through a grant from the United States Bureau of Fisheries, and the month of August was spent in work upon the lakes. In February, 1911, Mr. Juday visited some of the lakes to secure winter temperatures. A week in August of the same year was used in obtaining a second set of summer temperatures. The temperatures of Skaneateles and Owasco Lakes were also taken in February, 1912, and the early autumn of that year.

The stated purpose of the investigation was to extend to these lakes the studies on dissolved gases, plankton and temperatures, such as had already been made on the lakes of Wisconsin. A valuable technical report upon the results of the work was published by the United States Bureau of Fisheries, comprising tables, graphs, analyses, correlations, and discussions of the topography, hydrography, temperatures, dissolved gases, and plankton, with accompanying topographic and lake contour maps (Birge and Juday, '14).

No correlation of the results of this work with other conditions in the lakes has been made, and the relation to the fish forms of the lake appears not to have been considered. So far then, while of great scientific interest and value, the practical application of the results of the studies to fisheries problems, of which they are capable, remains to be made.

With the establishment of the State College of Forestry at Syracuse, a new agency concerned with the investigation of wild life of the forests and forest waters was initiated. The first publication on wild life was a study made of a worm disease of the Adirondack perch by Dr. W. M. Smallwood ('14), at that time of the State College of Forestry. In the summer of 1915 the College began a general, systematic survey of the biological and fishery problems of Oneida Lake, with the aim in view of working out a system or policy of fish culture for this lake.

Only a part of the results are yet in print. The first publication of this series was a report by Baker ('16), on the relation of Mollusca to the fish and other animals of the lake. As a result of the examination of the stomach contents of the fish, it was learned that Mollusca were a much more important element in the food of fish of this lake than could have been anticipated. Preliminary studies were made of the relative abundance of mollusks in the various bottom conditions of the lake. Baker concludes with regard to fish culture ('16, pp. 315, 316): "It is the culture of these animals that demands the greatest amount of reliable information. In the past some of the fish culture has been haphazard, fish fry and fingerlings being introduced into bodies of water without knowing whether the natural conditions were favorable or the food supply sufficient and of the right variety for their growth and multiplication. Before a planting is undertaken, it would seem the part of wisdom to know the food habits of the fish to be introduced and the general biology of the aquatic medium into which the fishes are to be placed. Thus we should know that the body of water contains plants for protection and suitable grounds for breeding, food sufficient in quantity and of the right kind, and the presence or absence of natural enemies which might seriously affect the increase of the planted fish. In other words there must be as nearly as possible a balance between the vegetation—the fish—and the food supply. Fish will be present and will persist in a body of water in proportion as the food supply is abundant or meagre and as the enemies are abundant or few in number. . . . There should be made a series of year-round observations on the aquatic life of Oneida Lake. These should be by months and should include the winter season as well as the more favorable summer, spring and fall seasons. That the fish life in the lake is more or less active through the winter season is known, but what these animals use for food is not well known."

In the introduction of the second report, having referred to foreign investigations, the author says (Baker, '18): "In America, while much biological work has been done on the qualitative side of fresh waters, few quantitative studies have been made aside from that of the plankton (Birge, Marsh, Kofoid, etc.) and a rich and almost virgin field lies before the ecologist who has the opportunity to carry on this important line of investigation. Such studies not only advance the technical or scientific side of aquatic biology but also the economic, so that both general and applied science advance side by side."

As has been said, the study by Birge and Juday of the Finger Lakes and that by Baker of Oneida Lake are both incomplete. Each lacks the study that the other received. Among other things, the Finger Lakes need quantitative investigations of the invertebrate fish food and definite knowledge concerning what fishes, occurring there, subsist upon plankton at any stage of their life. Plankton studies such as the Finger Lakes have received are needed for Oneida Lake, for complete knowledge applicable to rational stocking of a lake is necessary, and particularly as concerns habits and food of young fishes.

During several years Prof. W. M. Smallwood, of the Zoological Department of Syracuse University, made observations on Lake Clear in the Adirondacks, and later published a discussion of the fish and fish conditions in the lake (Smallwood, '18).

He says that the problem which confronted him was to discover the cause or causes for the obvious failure of this lake to support an abundance of fish after thirty years of restocking. Lake Clear was regarded as typical of a number of lakes in the Adirondack region, there being in the radius of fifteen miles more than seventy-five similar ponds and lakes of glacial origin.

Concerning the food supply for fishes he says: "It is to be regretted that in this lake the number of organisms suitable for food for fishes is so limited. The result is that each species comes into competition with the other species for food. *The result of this competition for the one abundant food, daphnia-cyclops, prevents this lake from permanently having large numbers of food fish.*

"The consideration of the history of the lake, the specific habitation of the fish, the noteworthy dearth of aquatic plants, the actual food of the fish and the restocking that has taken place during the past thirty years leads to the conclusion that restocking has not been and cannot be a success. In estimating how many fish any given body of water will support, one must first consider the variety and abundance of aquatic plants. *There cannot be any more animal food for the small fish and fingerlings than can find subsistence on the aquatic plants of any given body of water.*"

After reading this description of the lake and the conditions obtaining in it as presented by Professor Smallwood, and considering the number and kinds of fish that have been planted one is compelled to agree that the lake is a very clear object lesson in overstocking. It is shown that from 1887 to 1916, both inclusive, 17,535,850 food and game fish had been planted in this comparatively small and relatively barren lake. This number comprised five species, four of which were notably predacious fishes, consisting of brook trout (683,850); lake trout (1,067,000); rainbow trout (91,000); brown trout (6,000). The largest number of all is that of the common whitefish (15,688,000). These figures were furnished by the superintendent of the Saranac hatchery.

It would appear that the most signal success as concerns the present number of fish has been with the whitefish. This is not astonishing when it is known that food stated to be utilized by all ages of whitefish is the most abundant fish food in the lake, and when the large numbers of young whitefish annually planted are considered. It is inferred that of the other four introduced species, only the brook trout now occurs, and probably it may be inferred that the stock of both brook trout and whitefish is maintained by the annual restocking, and not by natural reproduction.

While Prof. Smallwood's opinion that even more extensive plants of brook trout in the past would not have increased the present brook trout supply in the lake is quite likely correct under past and present conditions, it is more than likely that a considerably greater supply of brook trout would have been maintained if no other species had been introduced, especially providing there are natural spawning beds for the trout in tributary streams. But as Prof. Smallwood says: "It is becoming more and more apparent that we must not only know the breeding habits of the small minnows, pumpkin seeds, etc., the fry of which serve as admirable food for the food-fish fingerlings, but also the natural history of all the life of a given body of water. It is a well-recognized biological axiom that no organism can live unto itself alone. This applied to our problem means that a clear and adequate supply of water is not the only factor that must be considered in deciding to restock great bodies of water with fish fry. But rather the intricate and more or less obscure conditions that determine the sum total of life in each body of water must be taken into consideration. Such studies alone furnish a correct basis for determining the extent to which an animal may draw upon a given source of food, upon the available body of food and many kindred problems. Before the State can wisely undertake to place more fingerlings in the ponds, it ought to know whether there is enough available food to keep them at least from starving."

Fig. 22. Quaker Run, Allegany State Park. A typical mountain trout stream.

Fig. 23. Coon Run, a trout brook tributary to Quaker Run.

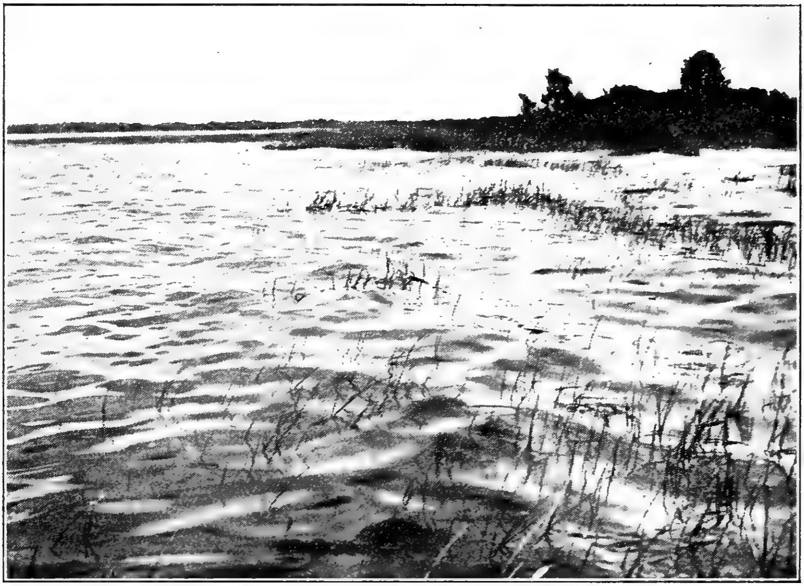

Fig. 24. A marshy lakeshore with heavy growth of rooted vegetation. Oneida Lake, New York.

Fig. 25. Dense cattail and water lily zone, along the swampy shore of Oneida Lake.

During August, 1918, and from June to the middle of July, 1919, a preliminary survey of the waters in Bear Mountain and Harriman Park sections of the Palisades Interstate Park on the Hudson River, was begun by the Department of Forest Zoology, and continued by the Roosevelt Wild Life Station of the New York State College of Forestry, at Syracuse, in cooperation with the Commissioners of the Palisades Interstate Park, and with the assistance of the United States Bureau of Fisheries. The examination did not cover all of the waters of the Park because of lack of time, but six ponds or lakes and two stream systems were reported upon (Adams, Hankinson and Kendall, '19). Concerning the waters of the Park the report says: "The waters present a number of unusual features which complicate the problem of fish culture more than is usually the case. The uses to which the waters of the Park are devoted are relatively more diverse than those of the usual wild waters. Furthermore the newness of the waters, having been formed or enlarged by dams, and their frequent changes of level, introduces uncertain factors which are not usually met with in fish cultural operations, and only time and further study can resolve this influence."

This is one of the few efforts that have been made to formulate a fish cultural policy for a large forest park where the recreational and educational interests are paramount, and where the officials wished also to see the possibilities of food fish developed as much as possible. There is a very general and extensive movement for the development of parks throughout America so that we may anticipate, in the near future, the need of intensive studies of this problem.

The New York Conservation report for 1919 says: "During the last year the Commission was requested to consider the advisability of a new hatchery to be located on Lake George. It is felt, however, that it would be more advisable first to make a complete survey of the lake, and reach definite conclusions as to which of the seventeen species heretofore introduced into the lake should be propagated in the future. It is futile to expect results from a great many species. It may be possible to determine to what extent angling in Lake George is inferior to that of some other lake as to certain of the game fishes, and to determine what species of game fishes may be expected to produce the best results. Having made this determination, vigorous efforts should then be made to produce those results with the species it is decided will produce the most food and sport. This same policy should apply also to other lakes. There are other important bodies of water, much used by fishermen, which at the present time do not appear to be producing the maximum results. Illustrations are Cranberry Lake, the St. Regis Lakes, Canandaigua Lake, and some of the Finger Lakes.

"Because of the necessity of determining questions of fish planting policy, if the best results are to be obtained with the product of the hatcheries, the Commission accordingly recommends an annual appropriation of not less than $5,000 for this purpose."

By an act of the Legislature of 1920 the Conservation Commission was authorized and directed to make a biological survey of the waters of Lake George for the purpose of determining the most practical methods of increasing fish production. For the purpose of carrying out the provisions of this act, the sum of $2,000 was appropriated. The Commission's report for 1920 concerning "Investigations in Fish Culture," says: "It seems strange that, notwithstanding the fact that the United States leads all other countries in the production of fish, and that the work has been going on now for over sixty years, there are a great many problems which no one in this or other countries is able to solve or even has attempted to solve. There is no up-to-date fish pathologist in this country. No one knows positively why it is impossible to produce under given conditions at one hatchery the same amount of fish as it is possible to produce under apparently similar conditions at another hatchery. It is possible to go on and enumerate many other phases of fish cultural problems which often enter into the work of the hatcheries and which are factors in the results obtained from planting fish in streams, ponds and lakes.

"During the past year this Commission has undertaken an investigation the nature of which differs from any ever before undertaken, in the biological survey of Lake George. In this work special investigations as to the relations of plant growth to fish food were made which have suggested the importance of more extended investigations along similar lines in other ponds and lakes where the fish cultural results have not been as satisfactory as could be desired."

In his report on the streams in Tompkins County Embody ('22) included some consideration of the principal lakes and ponds, to which later reference is made. This appears to be the first attention of the kind given to standing bodies of water by the Conservation Commission for many years. In 1922 a report upon the survey of Lake George was published by the Conservation Commission (Needham and others, '22). In the introduction Mr. Titcomb says: "Although the survey of necessity covered but a brief period of the summer months, it is probably the first and most comprehensive one of its kind ever made, embodying so many angles of investigation and having as its ultimate object the important economic problem of determining the most practical methods of increasing fish production."

Dr. Needham's report is not only comprehensive but delightfully comprehensible, being written in a style easily read and understood by the general reader. It is furthermore illustrated by cuts and diagrams easily followed by the lay mind. His report comprises the subjects of hydrography and environment, vegetation — including shore vegetation and free-floating microscopic vegetation,— the turnover of the lake's vegetation into fish food, and fishes. A summary and recommendations are also given.

Mr. Juday's report comprises limnological observations on Lake George. It covers essentially similar work as was carried on in the Finger Lakes: temperature of the water, quantity of dissolved oxygen and of carbon dioxide, quantity and vertical distribution of the plankton, and abundance of the bottom fauna in the deeper portions of the lake.

Dr. Moore's report pertained to the primary sources of food of certain food and game and bait fishes of Lake George. She says: " This investigation has sought to determine the nature of the food taken by the young of certain food and game and bait fishes of Lake George; and with such data as a basis, to seek further information on the primary sources of their food supply."

Mr. Sibley's part in the investigation consisted of listing the species of fish occurring in the lake, with notes on their feeding habits.

Mr. Titcomb's part consisted of fish cultural observations, he devoting his time " to ascertaining the viewpoints of anglers and guides as to past and present fishing conditions and their preferences as to species to be fostered.

" Investigations were made as to the relative abundance of mature fishes in the lake, angling conditions on the principal tributary streams, and with especial reference to the abundance of landlocked salmon in streams where planted for the especial purpose of stocking the lake. Particular attention was paid to the methods in vogue for distributing and planting the lake trout after their arrival at the Lake George railroad station."

The combined report is truly an excellent and enlightening one upon work well done, what there was of it. The investigations were all too brief and incomplete for the purpose of general recommendations as concerns conservation of the fishes and stocking of the lake. The studies indicate that the waters, except perhaps some tributary waters, are well adapted to various species, but there are much data lacking which must be acquired before rational stocking or conservation can be adequately undertaken.

In his recommendations Dr. Needham asks: " What can be done at Lake George to improve the fishing?" and adds: " My suggestions fall into two groups, I: Measures Immediately Applicable, and II: Measures Looking Toward the Future." Under each of these main groups general and specific recommendations are made, only a part of which will be mentioned here as the others do not appear to demand any comment.

The second recommendation with its subdivisions is, " Give more attention to the planting of hatchery-reared lake trout and more particularly:

" a. 'Acclimatize' the fingerlings to their new environment before liberating them in it. Get them accustomed to feeding on the natural food of the lake, and get them accustomed to a sight of their worst enemies.

" b. Plant them in water more than thirty-five feet deep.

" c. Scatter them widely in planting."

This recommendation is discussed in this paper under the subject of " Planting."

Under measures looking toward the future, the first recommendation is one well said and should be emphasized. It should have been "immediately applicable" or else the immediately applicable measure pertaining to lake trout should have been deferred to the future. He says: "Go out after more knowledge. Nothing else will serve as a basis of rational procedure. In all doubtful and difficult fish cultural practices substitute carefully planned studies for random observations and exact knowledge for hearsay. On every hand are problems in fish production with the limiting factors unknown. The cure for this condition is research."

To the present writer, the remaining recommendations and discussions of them, seem to be to the point and sound, excepting in one particular remark suggesting that the pike or pickerel is not a valuable species.

In Mr. Titcomb's introduction to these reports the recommendations, presumably derived from the individual reports, are as follows:

"1. That the planting methods for the distribution of lake trout be revised, and that they be planted as directed by the fish culturist.

"2. That the closed season on black bass be shortened so as to close October 31st."

3. [Pertains to protective patrol.]

"4. That the law for the protection of great northern pike or 'pickerel' be repealed.

"5. That anglers kill all rock bass and sunfish when caught, and if not utilized as food, take them ashore and bury them.

"6. That further efforts to stock the lake with landlocked salmon be abandoned unless some provision is made to rear them up to eight to ten inches in length."

The present writer questions the wisdom of the recommended repeal of the law concerning protection of the "great northern pike" or "pickerel," especially since the recommendation appears to be based upon general reputation and not wholly upon ascertained facts. In his general recommendations in this same report, Dr. Needham says: "Substitute carefully planned studies for random observations and *exact knowledge for hearsay*." (Italics the present writer's.) Yet, Dr. Needham evidently concurs in the recommendation, for which he gives the following reasons:

"The northern pike ('pickerel' of the local fisherman), is highly prized by some; but I have not included it among those I deem most worthy of propagation because of its voracious fish-eating habits. Early in life, certainly before the end of its first summer, it takes to a diet of fishes, and through later life it eats hardly anything but fishes; and it is a prodigious quantity of fish that one pike can consume in his time. The pike should probably hardly be considered an enemy of the lake trout, and perhaps not even a serious competitor; for it keeps to surface haunts and hardly invades the foraging grounds of the trout in deep water. But it certainly is both an enemy and a competitor of the shore fishes: doubtless it eats mainly herbivorous shore fishes like shiners, that are most easily captured; but it doubtless eats the game fishes as well when it can catch them. The chief reason for not recommending the pike is because its habits are such that no considerable increase in numbers of adults is likely to result from efforts to care for the young. It is only a sparse population of such fishes that any natural body of water can support. Grass-eating antelopes may flourish in large herds on the veldt but flesh-eating lions must of necessity have more room and be fewer in population."

Pound for pound, the pike does not exceed some other fishes, such as the lake trout and blackbass for instance, in fish-eating voracity or capacity. In fact if "hearsay" evidence is admitted, which it shouldn't be, the blackbass is alleged to have exterminated the pickerel in several lakes. Before taking measures to eliminate the pike, if it is indigenous to the waters of Lake George, would it not be better to "go out after more knowledge" concerning it and its natural relation to the balance of life in the lake, or in a similar lake where the balance has not been tilted to the extent that it has in Lake George, if such a body of water can be found?

The possibility of the pike being a factor in maintaining the former "balance of nature" has been discussed in another place in this paper (pp. 223-224).

Embody has discussed and made recommendations concerning the pike in Cayuga Lake (Embody, '22). He says: "Piscivorous fishes of large size must constitute an important factor in reducing the fish population in any small body of water. It is well known that the larger the individual fish above a certain weight, the more slowly it grows and the more food it requires simply for maintenance. It cannot be considered an economical practice to maintain a few giant fish at the expense of a large number of smaller ones. This is exactly what we are doing in permitting monstrous pike to simply maintain themselves where a large number of smaller fishes would grow and thus increase the amount of fish flesh.

"It is believed that there are many large pike from ten to twenty pounds in weight, in Cayuga Lake. One pike of thirty-seven inches, weighing nineteen pounds, had in its stomach a pickerel of eighteen inches and one and nine-tenths pounds in weight. It had consumed at one meal fish flesh equal to ten per cent of its own weight. It would not be an underestimation to say that no more than twenty pike of over eight pounds are taken in one year. The average size of those generally caught ranges from twenty to twenty-five inches long and from two to four pounds in weight. If all pike over twenty-eight inches long and weighing five pounds were eliminated, there would undoubtedly be more of the average size pike and certainly more of the other species of fish particularly yellow perch. It seems to the writer that for Cayuga Lake it would be much better for a number of fishermen to be able to make a number of catches of moderate-sized fish each year than for one or two fisherman only to be able to catch a very few giant fish.

"For this reason it is believed that the large pike which are seldom captured by angling should be taken out by commercial fishermen and put on the market as food for the community. If all pike over twenty-eight inches long were so captured there would undoubtedly be many more pike even above the average size, enabling the pike fisherman to better satisfy his desire for angling. It is known that pike first spawn when eighteen to twenty inches long and about three years old, therefore, a pike of twenty-eight inches will have spawned at least once and more probably twice or even three times, before it is large enough to be taken commercially."

Without considering the question of the practicability of regulating the size limit of the pike in the commercial fishery, it may be said that some of the points stated in favor of the recommendation are well taken. There may be a question, however, concerning the number of large pike in the lake. If they are very numerous why are not more of such "voracious fish of prey" taken by anglers?

It is a well-known fact that the proportion of overgrown fish to those of smaller sizes in any body of water is always small, and their number depends in great measure upon the extent of waters suitable to the species.

It may be true that the smaller fish of the pike family, and particularly yellow perch, would increase in number, but it may be a question as to the effect of such increase on the balance of life in the lake. Isn't it possible that increase in number of perch may result in decrease of some other organism upon which some other valuable fish depends for its maintenance — even the pike itself? It is quite possible that the value of the very large pike in the economy of the lake if it has any, is in the reduction of such forms that devour the food of young pike. But it is also commonly accepted as a fact that the very old fish are inferior in reproductive capacity, notwithstanding the large number of eggs produced. It may be that the elimination of the old fellows would give the younger breeders an advantage which would result in an increase in number and in better conditioned pike. However, this is all speculation, and speculation in this instance at least, except to indicate the necessity of investigation, is rather futile.

As concerns the Lake George pike situation Embody's suggestion applies only in reference to the size of the pike. It appears that at present the very large, old pike do not exist there, and those still found are comparatively small. So the big pike factor is eliminated at least for a few years.

Mr. Titcomb's reasons for his recommendation are stated as follows:

"The pike of Lake George, locally called 'pickerel,' is the great northern pike which occasionally attains a weight of thirty to forty pounds, but in Lake George a weight of twenty pounds would be very rare. Tarleton H. Bean, in 'Fishes of New York,' mentions individuals of sixteen and seventeen pounds, and tells of more than thirty examples averaging in excess of ten pounds, each of which was taken from the waters of Lake George during the season of

1889. He adds, 'The pike is a voracious fish and destroys everything within its reach in the form of animal life; other fish, water birds, and mammals are consumed in enormous numbers. From its concealment, like a beast of prey, it darts out suddenly on its victims and seldom misses its mark.'

"Dr. Needham's report confirms these observations. It is believed that the pike consumes twenty per cent of its own weight in fish daily. It is a prolific breeder, producing according to its weight anywhere from 50,000 to 600,000 eggs.

"Spawning takes place soon after the ice leaves the lake at which time the large pike may be seen lying close to the surface over a shallow weedy bottom.

"It is contrary to general practice to afford protection to northern pike in waters inhabited by lake trout and black bass, but some of the guides stand for its protection, and assert that neither bass nor lake trout are found in the stomachs of pike when caught. The writer is of the opinion that the pike destroys many smallmouth bass, and may be very destructive to the lake trout in winter when both species are inclined to extend their range. It undoubtedly is a factor in the decimation of the bullheads.

"In view of the foregoing it is perhaps fortunate that an epidemic has been raging among the pike, an epidemic said to have reached its height in 1919, when the number of dead pike found floating upon the surface of the lake was very great.

"It is recommended, that in view of the reputation of this fish, a modification of the special closed season on pike have consideration; or better still, that laws for their protection in Lake George be repealed."

Mr. Titcomb's reference to the egg-producing capacity of the pike is misleading, and Dr. Needham's description of the natural life-cycle of a generation of lake trout is particularly pertinent in this connection:

"Nature's method of propagating a species is indicated in our diagram, fig. 22 [not reproduced]. Here is seen a pair of adult fishes, be they lake trout or any other sort; it is the same for all. They produce a vast number of eggs, many of which are lost, while others hatch into fry. The fry are set adrift in a rough world in the midst of enemies and competitors, and many of them are killed or eaten, but some survive and grow to be fingerlings. So the process of elimination goes on, ever fewer attaining to larger growth, until at last two survive and lay eggs for another generation. The number of young produced is proportioned to the vicissitudes of life; there are only enough to insure the continuance of the species under natural conditions. This is what is known as the natural balance. It is one of the marvelous phenomena of the living world. It is true of every species in wild nature. There may be occasional ups and downs; but if we consider how things go through a series of years, we can readily observe that there are about as many individuals of any wild species through one decade as through another.

This means that any two parents, despite the large number of their eggs, succed in leaving on the earth but one pair of descendants that in turn reproduce."

From this it is seen that the fact that the pike produces a large number of eggs indicates that there are many natural adverse conditions operating against the species. The fecundity of the pike is a provision to offset them. Then, too, the natural longevity of the pike in addition to the capacity for egg production indicates that the vicissitudes of the pike race, notwithstanding the reputed voracity and savageness, are something prodigious. This being so suggests that when disturbances of balance occur, the advantages are likely to be on the side of some other factors or elements in the pike's habitat rather than on the side of the pike.

A "general practice" in the past, as concerns pike or any other fish, is hardly sufficient reason to condemn or favor it. Titcomb's opinion that the pike destroys many small-mouth blackbass appears to be supported by no evidence, and there is at least presumptive evidence that the blackbass may destroy the pike, as other reputed victims of the voracity of one species of pike have been observed to do. Brook trout have been known to take young eastern pickerel and the common chub or fallfish have been found feeding ravenously upon young of the same species (Kendall, '18).

Referring to the recommendation concerning rockbass and sunfish, both of which appear to be indigenous to Lake George, it would appear that the rockbass at least is a food fish of some value, although Needham omits it from his enumeration of the most valuable species of Lake George.

In the discussion of the fishes of Lake George, Titcomb says:

"The rock bass and two species of sunfish are very abundant about the shores of the islands and mainland. *They are easily caught, and furnish much sport for the little folks and for unskilled anglers.* [Italics are the present writer's.] Properly prepared, they are good table fish, either in chowder, cooked in the frying pan, or over the open camp fire. Many people do not care to skin and dress them and therefore throw them back. It is a practice of the anglers fishing for bass to return the rock bass and sunfish of which they catch perhaps six or eight for every bass they are able to kill. This practice is upsetting the balance of nature. In other words these fish which are rather objectionable in lakes of this character are being protected when the other more desirable fishes are being removed. It is better to kill them, and if not utilized as food to take them ashore and bury them."

To the present writer, the advice given in the last lines of the above paragraph and in the recommendation, appears strange, coming as it does from a fish culturist and conservation advocate. It is admitted that the rockbass is a good food fish. Bean ('03) says: "The rock bass bites very freely and is a fair game fish and excellent for the table." It is not shown in what way the balance of nature is being upset by failure to destroy the rockbass and sunfish. It does not seem to be a good policy to destroy those fishes just because the skilled angler catches more of them than he does of the fish he seeks. It is possible that "Nature" is already somewhat out of "balance" in Lake George, and that undue destruction of those fishes will effect still greater derangement. It surely is not good conservation to destroy one good food product because another is less plentiful or declining, especially when it is not evident that the comparatively smaller number of the one is even indirectly attributable to the other.

Considered from the sport fish standpoint, the question here arises: Are not the "little folks" and "unskilled anglers" to have any consideration? Are they to be deprived of the pleasure of catching fish because the "skilled angler" is not getting full satisfaction in his pursuit or because he is annoyed in that pursuit by some fish which he does not desire? The object of conservation of game fish is not only to provide the present but the future generations of anglers with game fish. If the "little folks" of the present generation can't attend the school afforded by their favorite fish, who will compose the future class of skilled anglers? We may go still further and ask whether the man who is equipped with a split bamboo rod, artificial flies, wading boots, and a pocket flask, is more an angler than the drowsy colored ge'man provided with a cane-pole and bob as he awaits the bite of a "cat," or "brim"? Or is the portly gentleman trolling a line from the stern of a boat rowed by a sturdy guide, more an angler than the barefoot boy with his alder pole, whose sport is afforded by sunfish and minnows?

> "O what are the treasures we perish to win,
> "To the first little shiner we caught with a pin?"

Are the interests of one class more important than those of another? Moral philosophy says: "No." Actual practice says: "Yes." Even so, in actual practice the problem always exists as to where to draw the line between the two classes of fishers and fishes.

The earliest biological examination of a stream in New York State of which there appears to be any account is that of Caledonia Creek, made over 45 years ago. A report upon it was made by Dr. J. A. Lintner ('78), State Entomologist. In the same publication Professor Peck reported upon the plants of the creek. Thirty years later, according to Dr. T. H. Bean, late State Fish Culturist of New York ('08), an examination of two streams was made concerning which he says: "At the request of Mr. F. C. Westfall of Oneida, an examination was made of two streams in the vicinity of Oneida, the Cowassalon and Skenandoa, with reference to their capacity for sustaining trout. The Cowassalon was found to be admirably adapted for brook trout and the Skenandoa for brown trout. Specimens of the natural food found under the stones were taken to the office and identified."

In 1915 the State of New York began the work of studying the streams of the state with the stated purpose of developing proper working plans for their systematic stocking, on the ground that the products of the State's eleven hatcheries, representing an annual commercial value of over $200,000.00, be distributed and cared for in such a way as to insure the maximum return for the money and labor expended.

Concerning the proposed study, Dr. Bean wrote ('16): "In order to devise more intelligent and effective methods of stocking and protection, based upon a thorough knowledge of the actual conditions obtaining in the streams and lakes, the Commission has undertaken an intensive investigation of the waters of the State. Some of the principal subjects for investigation are the following: the distribution and habitats of the fish found at present in these waters; their food habits, as determined by analysis of their stomach contents; the supply of natural food available, such as insects, mollusks, crustaceans, worms, and aquatic vegetation; the spawning seasons of the various fish; their natural enemies; stream pollution and methods of controlling it; proper open and closed seasons; methods of cooperation between the Commission and associations and individuals interested in propagating or protecting fish. It is confidently believed that this investigation will lay the foundation for a marked increase in the quantity, as well as for improvement in the quality, of the fishing in New York State."

The Sixth Annual Report of the Conservation Commission for 1916, says: "In the last annual report attention was given to the importance of making working plans for stocking the fishing waters of the State, *in order that the waste of the product of the state hatcheries, which has gone on heretofore* [italics the present writer's] after the fish have left the control of the state, might be checked. During the spring and summer and part of the fall two men, of the proper scientific attainments, were engaged upon such a study of the running waters of Oneida County. In this county alone there are approximately 2,000 miles of running streams, all of which were covered during the season with as much thoroughness as was necessary for the purpose of laying down working plans. The adaptability of the various streams for different kinds of fish was investigated, scout work to determine the proper planting points was done, and other data necessary for developing those streams to their highest efficiency as fish producers were obtained.

"These data include such facts as the degree of pollution, the temperature of the water, the food supply for fish life, the extent to which the streams are fished, and the local agencies that are available for carrying on the stocking. It was discovered that while some very fine work is done in certain sections, other large sections of the county have been totally neglected as far as fish stocking is concerned. At the same time the drain upon the streams, because of the increased use of automobiles has reached a point where they have become practically fished out. The results of the study of Oneida County are being embodied in a report to be published shortly. Systematic stocking in accordance with the plans given in the report will then be undertaken. This study opens a new field in fish culture and one which New York, with its large annual expense for fish hatching and rearing, could not afford longer to neglect."

The Conservation Commission report for 1917 says: "The stream survey of Oneida County, which was undertaken two years ago upon an experimental basis, has been completed and the results have been published in a bulletin and distributed largely throughout the county. This is the first time that the Commission has had available complete and absolutely accurate data regarding stream conditions over any large area. Strange as it may seem, the state has been shipping millions of fish for public waters without having authentic information regarding the suitability of those waters for the fish shipped. It is believed that the intensive study of Oneida County and the working plans that have been evolved as a result of this study will eventually overcome this difficulty for that one county. It is the intention of the Bureau of Fish Culture to obtain similarly reliable information as rapidly as possible for all of the State's public waters. This is absolutely necessary if hit or miss methods in fish planting are to be avoided, and if the efficiency which has already been developed in the hatcheries is to be extended to the streams."

The Conservation Commission report for 1918 briefly reviews the previous work in this direction and adds: "During the past summer a survey was made of Tompkins County by Prof. G. C. Embody of Cornell University, assisted by one of his students; and a full report on that county is in the course of preparation. Efforts were made to obtain men qualified to make surveys in other counties, but they were found to be practically unobtainable. The training required for this work is possessed by very few men and those who might otherwise have been obtained were engaged in war work. It is hoped that arrangements may be made during the next season to undertake surveys of the waters of other counties.

"So far only the running streams have been covered, because of the long time and special equipment necessary for lakes. It is desirable to undertake this work on the lakes as rapidly as possible, for the purpose of making them most productive of the species of fish best suited to them."

In the Conservation Commission report for 1919, reference was again made to Embody's survey of the streams of Tompkins County concerning which the report says: "Inasmuch as many of the streams have their sources in adjoining counties, it seemed advisable to complete the survey of the adjoining watersheds in other counties. This work has been done during the past summer under the direction of Prof. Embody, who was unable personally to give a great deal of time to it, but directed the work of the two assistants who worked in conjunction with him the previous year."

In 1917 the Conservation Commission published its survey of Oneida County streams by Clemens ('17). The following are stated to be the main points investigated and reported upon:

1. Source, length, width, depth and water into which each empties.

2. Character of the bottom.
3. Rate of flow.
4. Color and transparency of the water.
5. Vegetation in and along the stream and amount of shade provided.
6. Character of the surrounding country — whether timbered or open land and whether the stream is likely to be subject to drought, severe floods, or the inflow of a large amount of sediment from the watershed.
7. Temperatures from source to mouth.
8. Headwaters and spring tributaries were located as possible planting points.
9. Obstructions to the migration of fish.
10. Points at which pollutions occurred and the character, amount, and general effects of the pollution.
11. Presence of pools and side holes as places of shelter for fish.
12. Streams or sections of streams posted, and by whom.
13. The quantity and variety of food organisms for fish in the stream.
14. The kinds of fish present.
15. A few fish were taken from each stream for future stomach examination, in order to obtain more accurate data on the natural fish food.
16. As much local information as possible was obtained regarding the extent to which a stream is fished and the agencies available for carrying on systematic stocking and development.

After a discussion of the "broader issues," "working plans" are suggested, and detailed recommendations for streams follow. The specific recommendations are very brief, consisting principally of a statement of their fitness or unfitness for fish and the kind of fish to be planted in any instance.

It was not until late in 1922 that Embody's report upon Tompkins County was published. His report covers not only the streams but also to some extent the lakes and ponds. General conditions are discussed and more detailed consideration of each body of water is given than is the case in the Oneida County report.

Concerning "Brook Trout versus Brown and Rainbow Trout," Clemens ('17) says: "It has been proved conclusively that brown trout are very destructive to native brook trout. Hence in the working plans following, brown trout are recommended for only those river systems in which most of the water is no longer suitable for brook trout and where conditions give little promise of improvement in the near future. It is important to take the entire river system into consideration, and not merely individual streams, for brown trout planted in one stream in the system will in time work into the other streams, unless prevented by dams or other obstructions. Rainbow trout prefer large bodies of water and show a tendency to work down from the upper streams into the lakes and larger streams. They are somewhat destructive to native trout and should not be planted in brook trout waters. Because of these facts, there are but few waters in Oneida County in which it is advisable to plant rainbow trout."

Concerning these same species, Embody says: "It is believed that of the three trout the brown trout is the most predacious and most destructive of other fish and it is often stated that if a stream is stocked with all three species, the browns will eventually exterminate the others. There are many streams where brook trout have disappeared or become greatly reduced in numbers a few years after the introduction of brown trout, but it has in no case been proved that brown trout has caused the trouble. In fact there are streams in Tompkins County where the brook trout and brown trout occur apparently in equal numbers and have lived so for a number of years. The Van Pelt Brook is perhaps the best example. This matter is important enough to merit investigation. But until something more definite is known, it is well not to take any risks and those who have studied the question deem it wise to keep the coolest and purest streams for brook trout only, except in some cases where rainbows may be advantageously introduced."

Embody discusses also other stated habits of the brown and rainbow trouts, but it does not appear to have occurred to either Clemens or Embody or their predecessors in trout study, that real incompatibility might be indirect rather than direct. Given three individuals of the same size, one of each species, it may be a question which is the most "predacious." From the statements of some "authorities" it would appear that the advantage on the part of the brown trout is due to the large size it attains (figure 21). Within its natural growth limitations the size attained by any fish is in a great measure dependent upon the quantity and quality of its food supply. It is axiomatic that any stream can provide only a certain amount of animal life. It has been claimed that the optimum of favorable conditions for the three species in question differs somewhat, but these favorable conditions seem to overlap. Given a body of water of optimum favorable conditions for one of the species but which the other species nevertheless find congenial, might it not be reasonable to expect that the first mentioned would ultimately crowd out the others, not necessarily because it eats the other two forms but because under optimum conditions it is a competitor of greater capacity for the food supply? This might and probably would, in some cases at least, react upon this fish itself in that during the period of competition it is deprived of more or less food, but such reaction would again be relieved if the fish were driven to eat the other species, or if the other species were driven out. Then the natural food supply could be expected to again increase to a maximum. This situation might exist in connection with any one of the three species mentioned. As Embody says, it merits investigation. However, to the present writer's mind the point is that no more than one species of the trouts should be planted in the same place. If a stream possesses optimum brook trout conditions in one part, optimum brown trout in another and optimum rainbow trout conditions in another, and if the optimum conditions of one are unfavorable to the others, it appears logical to believe that each species would seek the portion of the stream in which the most favorable conditions occur, and that the tendency would not be to an extensive invasion of the domain of the others.

Both Clemens and Embody have made recommendations for planting the fish which conform to a great extent to this idea, although apparently for different reasons.

After all, the fact is that speculation does not decide any question and there is still need of just such commendable investigations as those conducted by these two biologists, but they should be extended to other waters and include a thorough study of the habits of the fish themselves. Until this is done, as Embody remarks in effect, it is better to play safe.

The Conservation Commission report for 1918, in connection with the subject of "Stream Study," says: "So far only running streams have been covered, because of the long time and special equipment necessary for lakes. It is desirable to undertake this work on the lakes as rapidly as possible, for the purpose of making them most productive of the species of fish best suited to them."

In 1920 a fish survey of waters in western New York, by the Roosevelt Wild Life Forest Experiment Station, of the New York State College of Forestry at Syracuse, was begun, in cooperation with the Erie County Society for the Protection of Birds; the Buffalo Society of Natural Sciences; the Springville Rod and Gun Club; the Boston Valley Fish and Game Club; the Cazenovia Valley Fish and Game Conservation Club; and the Akron Forest, Field and Stream Protective Association. The work was confined largely to streams of Erie County, but some attention was given to a few waters of Niagara and Genesee Counties.

In 1921 a preliminary reconnaissance of the streams in Allegany State Park and vicinity was started by a party from the Roosevelt Wild Life Forest Experiment Station, under the immediate direction of Mr. T. L. Hankinson, Ichthyologist of the Station.

Concerning the work, Mr. Hankinson says in his report (not published): "Such a short time could be spent at the Park in 1921, and so much ground had to be covered in this preliminary reconnaissance that little could be learned of the fish of the region. The data in this report, then, can be of value in connection with those to be obtained later, but they are insufficient for any important or definite recommendations for a fish policy for the park or for any body of water in it."

Collections of fish, other aquatic vertebrates, and aquatic invertebrates were made; photographs taken of all the places where collections were made and with every collection a record was made of the following: locality, date, weather, air and water temperature, rate of water flow, depth, character of the bottom, clearness of the water, vegetation of the shore and stream bed, vertebrates associated with fish, etc. Collections were made in the following streams:

Allegheny River, Great Valley Creek, Little Valley Creek, Quaker Run system (figures 22, 23), Red House Creek and Wolf Run. Twenty-six species of fish were collected, including three game fish, — brook trout, rainbow trout and brown trout.

Brook trout were recorded as abundant in the Quaker Run system and a few were found in Wolf Run. A few rainbow trout were found in Quaker Run, also a few brown trout, but the latter were said to be common in Red House Creek.

In August, 1922, a continuation of this Allegany State Park survey was made more intensively by the examination of the Quaker Run system by a party from the Roosevelt Wild Life Forest Experiment Station, under the immediate direction of the present writer. The aim of this survey, as in the case of that of the Palisades Interstate Park, was to work out upon a broad basis a general fish cultural policy for the Park. Quaker Run was examined from near its source down to the Park Headquarters. All of the tributaries with the exception of Coon Run were explored, most of them from their source to their junction with Quaker Run. The streams were carefully examined in sections, each day a different section, and detailed notes were made of the character of the streams and immediate banks. Collections were made of the fishes and aquatic invertebrates, with the aim of determining the abundance and distribution of the various species of fishes, and the quantity of food for trout. A rough survey was made of the dimensions of each section and an effort was made to count the trout in each section, to which census the clearness of the water and openness of a greater part of the stream lent itself beautifully. In Quaker Run, brook trout were found from the extreme upper limit of examination down to the beginning of the open country just above "headquarters," and in all the tributaries throughout. Only two adult brown trout and one fingerling were seen, and only a few small rainbow trout were observed in Quaker Run and these in the lower sections.

This appears to be the first time that an actual census of trout of an entire stream has been attempted. It is believed that a fairly accurate count was made, and they were roughly classified by estimated lengths as: fingerlings; large fingerlings; 4–5 inch, 6–7 inch, 8–9 inch, 10 inch trout; and up. Probably there are but few places so admirably adapted to such work as in these brooks. It was hoped that it would be possible to correlate the number of fish observed with the numbers planted in different years, but the information concerning the number planted was found to be unreliable. However, if accurate records are kept of future fish plantings another census would be of interest and value in relation to stocking and maintaining the fish of the streams, and particularly as concerns the capacity of the streams to support trout of any kind. This information would serve as a guide for recommendations as to kinds and numbers of trout to plant in the various waters.

GENERAL PRINCIPLES OF STOCKING INLAND WATERS

As pertains to stocking or restocking of waters, there are a number of essential ecological conditions that require attention. It is desirable to know not only to what kinds of fish a body of water is suited but also how many of each kind it can sustain, maintain and retain. Its sustaining power in a measure depends upon the quantity and quality of the food supply; that of maintenance depends upon the perpetuity of its food supply and upon adequate breeding places, or annual plants of fish; the number that can be retained depends upon the habits of the fish, intercommunications of waters and the control of the fishery. One of the essential conditions to consider, then, is biological capacity.

Food Producing Capacity of Fresh Waters. It has been long known that the fry of a great number of fishes feed upon minute Crustacea and small insect larvae which live in the water. Because of this relation, for many years it seemed that the solution of fish culture depended to quite a degree upon our knowledge of these small organisms, both plant and animal, which floated about in the water, the plankton. This stimulated many quantitative studies of the plankton in the Great Lakes and other smaller ones by Reighard, Ward, Birge, Marsh, Juday, and others, particularly in the lakes of Michigan and Wisconsin. Kofoid made an extensive study of the plankton of the Illinois River ('03, '08) and his investigations, among other conclusions, led him to believe that the submerged aquatic plants were a vital factor in the production of plankton; the more abundant this vegetation, the less abundant the plankton. Pond ('05) later modified this conclusion and showed that the amount of plankton, other things being equal, is in an inverse ratio to the amount of its gross non-rooted vegetation, and in a direct ratio proportional to the amount of its gross rooted vegetation (figures 24, 25). He concludes as follows (p. 525): "If we accept the conclusions reached in this paper that gross rooted vegetation is favorable to plankton production, and if we further accept the current argument that fish production is dependent on plankton production, the practical applications of the results of this investigation are simple. In the stocking of ponds for fish culture care should be taken to have a good soil for the bottom; not a stiff clay nor sand, but a good loamy soil, such as is favorable for land plants. The species allowed to grow should be those which are known to possess roots and to be very dependent upon the soil, such as *Vallisneria spiralis,* the so-called eelgrass, and *Potamogeton,* or pond weeds; not forms without roots, such as *Ceratophyllum,* or those less dependent upon the soil. In natural lakes choked with a growth of *Ceratophyllum,* the removal of this form and the substitution for it of rooted plants offer possible means of increasing the supply of edible fish.

"The poverty of the Great Lakes in plankton may be attributed to several causes. One of these is, doubtless, the relatively small shore area in these waters occupied by rooted aquatics. The com-

Fig. 26. Swarms of mayflies, Oneida Lake, New York. An example of surface fish-food, at times remarkably abundant.

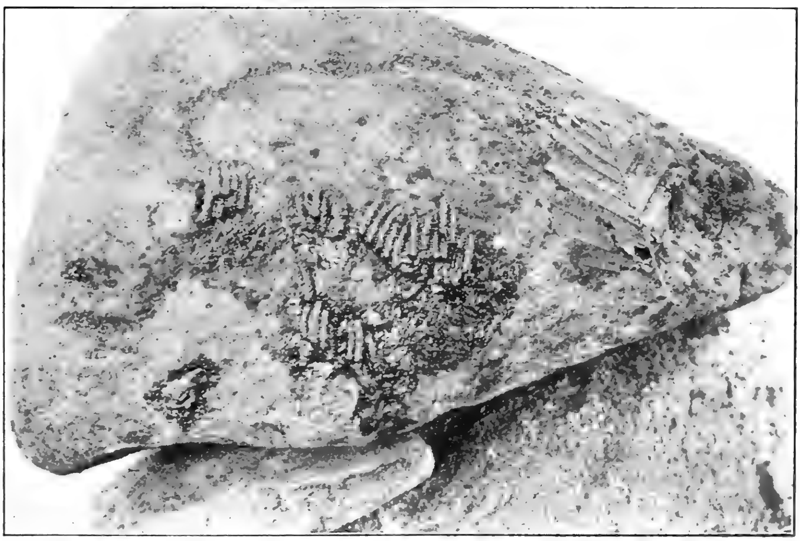

Fig. 27. Caddisfly cases, along a brook in Palisades Interstate Park; an example of bottom fish-food.

paratively short shore line, the narrowness of the shore area, and the mechanical action of the waves, all tend to limit the growth of rooted plants, hence to limit the productive capacity of the lake in plankton and, according to the current belief, in fishes."

But in addition to the minute animal food in the water the older fish in general require still other food materials, such as the gross forms living on the bottom. Investigations of their character were long neglected, so that it remained for F. C. Baker ('16, '18) of the New York State College of Forestry, to take up this subject in a quantitative way in his investigation of Oneida Lake. Baker's studies showed very clearly that 88 per cent of the gross invertebrate population, or fish food, was found upon the bottom within the six-foot contour line. It was also found that life was most abundant in sand and the poorest upon boulder bottom. These were the first investigations of the kind in America. About the same time, somewhat similar qualitative studies were made in Lake Mendota, Wisconsin, by Muttkowski ('18), and very recently the Mollusca have been studied in Lake Nipigon in Canada by Adamstone ('23). The only similar European study was made in Sweden in Lake Vättern by Ekman ('15). (Cf. Baker, '18, p. 252; also Clemens and others, '23, pp. 171–188.)

Thus, these studies of the minute and gross fish food (figures 26, 27) in the waters will serve as a foundation for future studies which aim to determine the fish food producing capacity of our inland lakes and streams. Such studies must be extended and intensified before we have a really adequate basis for fish culture in public waters.

We now need intensive study of the habits of the young of all our important fish, in order to know their normal haunts and food as correlated with the normal food supply in our lakes and streams. As Baker ('18, pp. 208–218, 224) pointed out in his study of Oneida Lake, one of the next important steps will be to determine the *amount of fish food* which fish need for definite periods throughout life. Until this information is secured, as well as the amount of food which a given water can produce, we will remain in the position of a farmer who does not know how much pasture he has or how many cattle he has to be pastured.

Breeding Grounds. Not only must fish have proper food and proper physical and chemical conditions of the water in order to maintain themselves, but for permanent maintenance there must be available suitable conditions for breeding. The breeding conditions and habitats vary greatly for different kinds of fish. Some deposit their eggs upon gravel shallows in rapid streams, some upon rocky shoals or bars, others upon quiet sandy or gravelly bottoms, and some among vegetation. The great majority, however, breed in shallow waters; and it is in such conditions that as Baker has shown for Oneida Lake we find the greatest abundance of fish food. This is a significant indication of where certain species of lake and pond fish should be planted.

The character of the breeding grounds may be changed or destroyed in many ways. Sand, soil and other materials, such as sawdust and other débris, may be washed upon the breeding grounds and thus make them unfavorable. Severe erosion may clog the channels of streams and destroy the breeding grounds as effectively as a driftwood dam or a beaver dam may destroy a shoal or riffle in a brook or creek. Even the growth of vegetation upon the breeding grounds may injure them, although some fish will clear away such plants when they form their nests.

When periodical planting is intended to wholly replace natural breeding conditions of course the breeding habitat is correspondingly reduced in importance, but on the whole this is a very expensive policy and is of very doubtful applicability to public waters. Otherwise, provision for such grounds and their protection is of the greatest value. The changing conditions of these grounds, and the life of the eggs and fry while upon them, are in urgent need of very careful study. Today this is one of the weakest points in fish culture.

Relation of Volume of Water to Capacity. It is not necessary to call attention to the possibilities of depletion from unrestricted fishing by an unlimited number of anglers. "Artificial" propagation and due regard to conservation greatly reduces the danger. Yet there is a limit to the efficacy of artificial stocking of waters imposed by the limitations of biological capacity, the significance of which is that it is possible to conceive of so many anglers that the waters could not support enough fish to afford good fishing to all; also that there would be danger of overstocking in any attempt to meet the demand, which sooner or later would result in general depletion. Of course there is at present no generally satisfactory way to limit the number of anglers in public waters, and the customary limits in size and quantity of fish and in angling methods are about the only feasible restrictive measures. This point, too, involves a consideration of biological capacity. Amongst other considerations biological capacity involves the volume of water and its physical characters, as waters differ not only in respect to the number of fish they can support, but in the kinds of fish to which they are suited and the size to which the fish can attain in them.

In respect to volume and physical characters bodies of water differ greatly. There are standing bodies of water comprising lakes, ponds, pools, springs, etc., and moving waters designated as rivers, streams, creeks, brooks, runs, etc., and there are waters also which may be regarded as more or less intermediate between the two classes. Many of these contribute to one or the other both physically and biologically. All of these conditions should be taken into consideration in stocking, for success or failure may depend upon one or another of the characters.

Lakes and Ponds. Recent terminology affords no definition to distinguish a lake from a pond. Webster's Dictionary defines a lake as "A considerable body of standing water in a depression of the land; also, an expanded part of a river." Also, "when a body of standing water is so shallow that aquatic plants grow in most of it, it is usually called a *pond;* when the pond is mostly filled with vegetation it becomes a *marsh.* Lake basins have originated in many ways, but mostly through glaciation." A pond is defined as "A body of water naturally or artificially confined and usually smaller than a lake; in England, usually, except locally, a body of water artificially confined."

In some localities comparatively large bodies of water which used to be called ponds are now lakes, and the name lake is often locally given to inconsiderable "bodies of standing water in a depression in the land." The largest inland body of water in Maine, Moosehead Lake, has always been known as a lake, but the second in size, now Sebago Lake, was once "Sebago Pond." A small body of water near Portland, formerly "Duck Pond" is now "Highland Lake." Thus the terms lake and pond have become quite generally synonymous, and in this discussion they must be so regarded.

Lakes and ponds vary greatly in character in different sections of the country and often in their different parts (figures 28, 29). In the northeastern states the majority of "considerable bodies of standing water in a depression of the land" are glacial and post-glacial in origin. In many respects, although greatly differing in size, they are very similar in character. There are also variable extents of river expansions, as well as considerable bodies of water set off from a river, lagoon-like in situation but too large to be called lagoons, that have been termed lakes.

While this paper does not aim to include artificial ponds in its discussion, reference should be made to certain bodies of water of variable size and character which perhaps may be called semi-artificial ponds. For those who desire information on artificial ponds reference should be made to Embody ('15), Johnson and Stapleton ('15), and Titcomb ('23). Ponds of this kind are those which have been formed by damming a stream (figures 30, 31), but which have developed into or remained in a more or less wild state, such as some millponds, water storage reservoirs, ice ponds, or beaver ponds, or they may have been originally intended for fish ponds. They vary in size and character according to circumstances, and in general may be much like some other natural ponds. Some well-known lakes and ponds were thus formed or increased in size by having been dammed by the action of ice or floods in glacial or post-glacial times. These, however, are all under the head of natural lakes and ponds. The history of all recent semi-artificial ponds subsequent to the formation of dams has been much the same, depending upon the obtaining local conditions. Nearly always the result has been more or less rise in the temperature of the water. Often water plants accumulate in shallow water, and always there is a gradual accumulation of silt and débris in shallow water at the mouths of inflowing streams which gradually encroach upon the depth of the pond, so that sometimes the bottom thus formed rises to the surface as "floating islands" (figure 30). Many small ponds have been filled with such accumulation and become mere frog ponds or even quaking bogs. The outlets of lakes or ponds of such character are almost always lowered to such extent that they are practically dry in summer.

In time the animal life of these ponds, particularly the lower forms, also increases in quantity and changes in character. But unless by the instrumentality of man the fish life has seldom been changed in character, although it might be in quantity in one way or another.

The kinds of fish suitable for such ponds vary with the character of the pond, as in the case of natural ponds. So in stocking the physical and biological conditions must be ascertained just as in the case of natural ponds. In restocking, guidance may be provided by a knowledge of the original inhabitants, but as in the case of natural ponds, this is not always a safe criterion, for the pond may have greatly changed since it was occupied by the original stock, and even the original stock may have existed only by tolerance and perhaps in much smaller numbers than some new forms would provide. So as in the case of natural ponds, each sort of pond furnishes its particular problem.

Streams. The term stream is a comprehensive one, even when restricted to water courses. A river, brook, creek, run or rivulet, is a stream. But among our common names for streams there is no definite rule to enable us to distinguish by name a river from a brook by the size. Webster defines a river as a natural stream of water larger than a brook or a creek, and brook as a natural stream of water smaller than a river or creek. The creek is an inland stream, stated to be smaller than a river, larger than a rivulet or a run. A rivulet is "a small stream or brook; a streamlet," and is synonymous with rill. A run as applied to streams is "a brook, a stream, a watercourse." Thus only in a general way does the dictionary enable us to distinguish one from the other. Common usage also is about as obscure.

Few streams are relatively non-fluctuating in volume through the different seasons (figure 33) or uniform in character throughout their course, and therefore vary more or less in suitability or capacity for any one kind of fish. Such variations may be permanent or temporary. Permanent variations in a measure determine the fish fauna of the different areas. Thus only one or two species may occur in the upper and several in the lower waters, as for example brook trout in the upper portion and pickerel and suckers or other species in the lower section. Then again a stream is often interrupted by rapids or riffles and intervening still water sections, as so-called "dead waters," and pools. Such localities often afford the occasion for seasonal movements of fish for breeding, feeding or safety.

Temporary variations are such as are caused by seasonal changes (figures 32, 34, 35), as in height of water, temperature, etc. These variations may also be the occasion of more or less migratory movements of the fish inhabitants of the stream or a section of it.

As concerns game fishes and their relation to their physical and biological environment, while lakes and ponds in some ways and in some localities may be considered as distinct, in other ways and in other localities they are intimately bound together and cannot be considered otherwise in connection with certain fishes.

There are some fishes which pass their entire life in a lake or in a stream, at no stage of their existence migrating from one to the other. Again there are others which pass a part of their life in the lake and another part of it in a stream. Certain primarily lake fishes enter streams to breed, and cannot successfully breed elsewhere. The young of some of these pass their early life, which may be from a month or two to a year or two, in the stream. The young of still others almost immediately after hatching either actively or passively enter the lake. Still others which are hatched in a lake soon after birth make their way into streams. In some streams phenomena similar to those mentioned in relation to lake and stream are observed in the relation of the larger stream to its tributaries. So in planting fish in lakes or streams it is essential to know what their habits are in this respect, for upon that knowledge successful stocking to a great extent depends.

The relation of lake and stream or large stream to smaller stream, however, is not restricted to propagation and young fish. Some fish enter tributary streams from a lake or large stream as adult fish for other reasons than that of propagation. It may be for food, or it may be for some other reason, as temperature, for instance. The sojourn in these tributary streams is more or less temporary. For example, there are known instances of brook trout leaving a lake and appearing in considerable quantities in a tributary stream where they remain for some time, then disappear, and absolutely no trout of any size can be found there. Still other instances, capable of definite citation, are those where large trout occur and remain in the lake and never ascend a stream, unless to spawn, and sometimes not even for that purpose. But small trout up to ten inches or so in length ascend the brook in the spring, or summer, during stages of high water in the brook and return to the lake when the water of the brook subsides, or warms up. Sometimes also, while large trout spawn in the lake, smaller trout ascend the streams for that purpose and remain there all winter, returning to the lake in the spring or summer.

Suitability of Waters for Fish. A utopian wish of the fish culturist is for a simple method by which he can determine the favorable localities and conditions in which to plant fish. The oldest method is similar to that of the pioneer farmer who in the virgin forest chooses the land for his farm by selecting the land with the best forest. He assumed that, generally speaking, the best soil produced the best timber. The fish culturist has tended to assume that waters already having thriving fish are favorable waters. This method still remains the most practicable for remote or inaccessible waters. In the old days this was about all that was needed or expected, but condi-

Fig. 28. An exposed boulder beach, with scant water vegetation. Oneida Lake, New York.

Fig. 29. A sandy bay, Oneida Lake. Note the dark colored windrows of mayflies cast upon the beach.

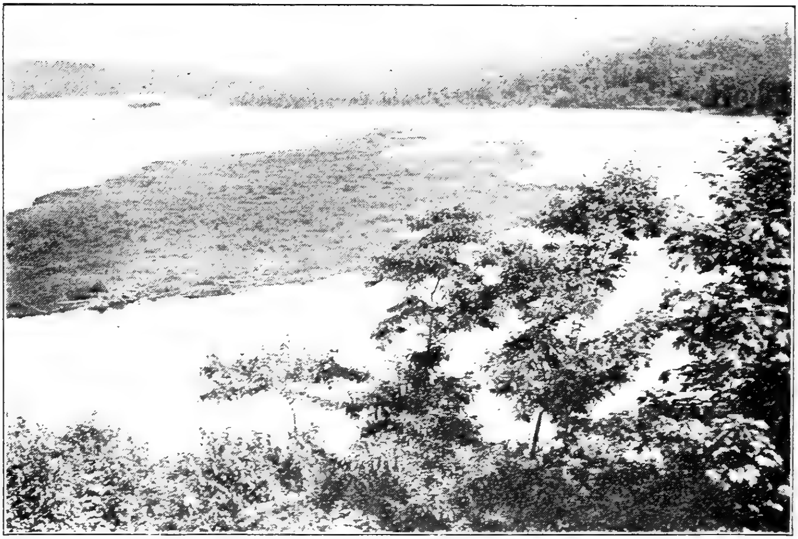

Fig. 30. A lake formed by damming a brook; the large floating island is a mat of the loosened bottom turf. Kanahwauke Lake, Palisades Interstate Park.

Fig. 31. The brook that feeds Kanahwauke Lake. View taken below the dam

tions have now changed greatly, and no one can tell when to expect, even in remote woods, a sawmill or some mine or industrial plant, which drains or throws its refuse into streams and lakes. With the automobile these remote waters are now relatively accessible, and over-fishing is a condition that cannot be ascertained by an inspection of the waters. Probably the greatest handicap is that the time available for such considerations is very limited, few have the training to make such determinations, and finally the amount of waters needing examination are so extensive. There are thus many difficulties which usually prevent the proper study of this problem.

Indexes to Fish Habitats. Many efforts have been made to find simple accurate methods of measuring the suitability of waters for fish. Shelford and his students (Shelford and Allee, '12; Shelford, '14, '18a, '23; Wells, '18) have given much attention to this important subject, particularly to the chemical conditions, and the influence of the chemicals on fish. As Shelford ('14) points out, the common methods are three in number: 1, inspection of the bottom, largely to determine the presence of organic débris; 2, chemical tests, largely for decomposition products; and 3, the presence of index organisms known to indicate certain conditions.

Shelford ('14, pp. 29-30) states that: "If a body of fresh water is to support the most desirable fishes it should have an area of clean sand, gravel or other terrigenous bottom covered by from six inches to two feet of water and an area of emerging and submerged vegetation to supply food. It is probable that for the best results these three areas should be about equal. . . . Since most bodies of water contain sufficient vegetation to supply insects and other food for more fishes than can exist there, *the amount of terrigenous bottom up to one-third of that occupied by vegetation may be regarded as an index of the suitability of the body of water for food fishes.*

The second index is essential but must accord with the first. The chemical character of the water must be such that the fishes will not suffer from it or leave on account of it. Carbon dioxide results from the decomposition of organic matter. In the process oxygen is consumed so that the presence of any quantity of carbon dioxide nearly always indicates lack of oxygen. Fishes are very sensitive to carbon dioxide, turning back from increase of one or two cubic centimeters per liter of the gas in solution. . . . *Thus the amount of carbon dioxide may be taken as an index* of the suitability of the water." (Cf. G. M. Smith, '23, p. 135.)

Wells ('18, p. 568) has further shown by experiment that: "The more resistant species are found in ponds, shallow, muddy-bottomed lakes, or in the stagnant pools of streams. These are the fishes which one sees in aquaria. They are able to withstand increased temperature and wide fluctuation in the oxygen and carbon dioxide content of the water, and to some extent are able to live in the presence of the excretory products of their own metabolism. The stream fishes proper can not do this, and therefore die when placed for any length of time in standing water."

" In general, the resistance of fishes is correlated with the environment in which they are found. The more resistant species are found in ponds and shallow lakes while the least resistant fishes occur in the swift streams and in cold, deep lakes."

Very recently Shelford ('23) has again discussed rather fully the influence of hydrogen ion concentration upon fishes and other aquatic animals, and points out that the chemical methods for their determination are not yet perfect to such a degree as to determine the relative value of this factor. The perfection of the various chemical methods to a point of devising relatively simple field methods will be of great value in fish culture, as well as for other purposes.

Methods of using index organisms or communities of organisms, that is, different kinds of plants and animals whose characteristic presence in water indicate its chemical and other conditions, seem destined to become of considerable importance in determining fish habitats, because of their ready application to field conditions.

Temperature. The usual fish cultural test of suitability of waters for receiving young fish has been the temperature of the water. As concerns certain species of fishes the range of temperature in which each species will thrive, or the extremes of which it can endure, has been approximately determined. But temperature alone is not the all-controlling factor. There are other essential factors to which, in some cases at least, temperature is secondary, as, for instance, when a fish " seeks " a water condition which is colder than that which it leaves, although the temperature in the latter place may be well within its particular " temperature range." In such instances some other factor, as oxygen, may be the controlling factor, for it is known that lowered temperature signifies greater absorption of oxygen, at least under certain attendant conditions, as for instance in the rapid water of a stream of clear or pure water.

Space will not permit of any extended discussion of bio-physico-chemical conditions which are intimately bound up with temperature conditions, and in this connection it is hardly necessary, for after all, temperature is often a fairly good guide. Yet in an investigation all of the factors must be considered in order to learn the significance of many phenomena connected with fishes, the causes of which are obscure.

There are at least two artificial conditions which modify biological capacity, but the extent and the effect of which are not always clearly known. One is that of pollution and the other physical obstructions.

Pollution. Pollution has been accused of all sorts of harmful effects upon fish, and in many instances justly so. But in the words of Evermann ('94), " we know that vast quantities of sawdust and vast amounts of refuse from paper-mills and other factories are let into our streams, and we know, perhaps, that great mortality

Fig. 32. High water conditions in a large stream in spring. Chittenango Creek, New York.

Fig. 33. An example of a stream remaining full through the summer season.

Fig. 34. Red House Creek, Allegany State Park, in summer. An example of a stream which fluctuates greatly in volume.

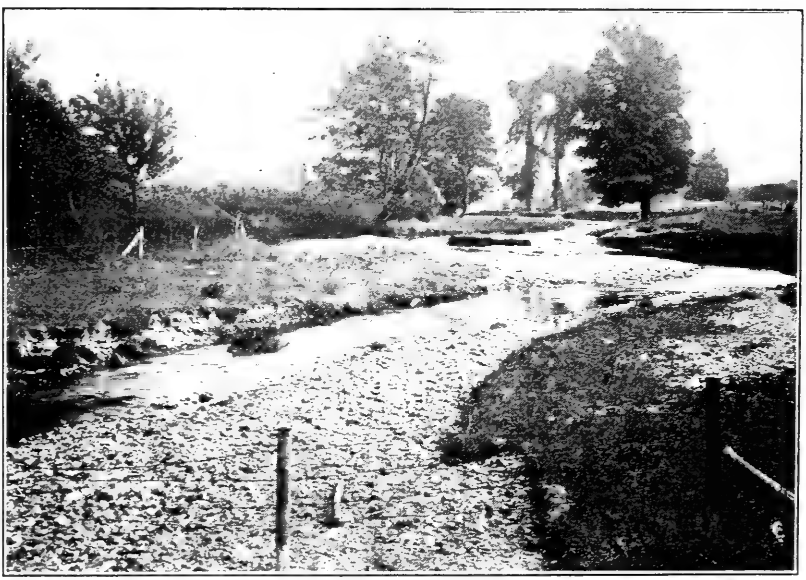

Fig. 35. Glenwood Brook, Erie County, N. Y., in summer. Note the evidence of much greater volume at certain seasons.

has occurred with the fishes in some of those streams; but do we *know* that *one* is the *cause* of the *other?* We *think* that sawdust injured the fish, but do we *know* it?"

Doubtless the foregoing questions were asked to emphasize the necessity for scientific investigation to prove or disprove prevalent views concerning the subjects before trying to regulate them,—not that Evermann himself probably doubted that certain kinds of pollution at least were injurious to fishes. There can be no doubt of that, for it *is known.* At first, however, it was inferred. The direct effect of certain chemicals upon organic substances was well known. It was therefore supposed that these chemicals would be injurious to organic life in a stream. There could be no doubt that in concentrated form they would be. How much dilution would render them harmless to fish life, or whether the water in the stream would sufficiently dilute them was not known, and although many investigations both in laboratory and in the field have been made, the questions have not been settled to the extent that the results can be applied to every instance of pollution. Inferences are at times apparently justifiable. For instance, when a stream once frequented by fish is now deserted, and no other modification than excessive pollution has taken place, it is not a wild guess to attribute the fact to pollution. Such a case is the Passaic River in New Jersey. When streams were frequented by fish up to the time mines were opened on the banks, and as soon as mine waste was discharged into the rivers the streams were forsaken by fish, it would appear reasonable to attribute the disappearance to mine waste. On the other hand, when cases of polluted streams frequented by fish are cited, what answer can be given?

It is necessary to ascertain the extent of the pollution and its effects upon other organic life rather than directly upon the fish themselves, for the deleterious effects may be upon the food supply or some other essential condition. It is necessary to ascertain whether the stream is actually frequented by fish more than temporarily. Certain fish may at some time or other ascend a stream which is more or less polluted. They may not encounter sufficient pollution to seriously affect them, or to turn them back, until a long way upstream. The spawning places may be so polluted that the fish cannot propagate. Their migration, in such instances, has been in vain so far as the perpetuation of the race is concerned. Or even if the fish spawn in polluted areas, the eggs may not develop and no young fish be produced.

W. C. Adams, of Massachusetts, says ('21, p. 29): "Observations were made on the conditions in the Merrimac River, not for the purpose of isolating and analyzing the different types of pollution, but rather to determine whether any fish would frequent these waters in their present state of defilement, and to observe something of the fish life in the river. As stated elsewhere, the belief has been general that the condition of this river was such that no migratory fish would frequent it. This has proven to be erroneous by the presence of alewives in the fishway at Lawrence during the past spring." In another place in the same report he says (p. 84), "The results from the Lawrence fishway are particularly interesting, inasmuch as some of the foremost fish experts in the United States have held the opinion that the pollution of the Merrimac River would prohibit the use of a fishway by anadromous fish, and that fresh-water species would make little use of such a structure. We now know that alewives have passed through the fishway in spite of the pollution, and that the fishway has been used by various species of fresh-water fish."

The table of records of fish which were observed in the fishway including anadromous fish above it, from May 25 to July 6, comprised 72 alewives, 19 suckers, 105 shiners and dace, 44 eels, 3 trout, 1 sturgeon, and 1 carp.

This proves nothing beyond the fact of the possible efficacy of the fishway. Nothing is stated concerning the extent of the pollution at this time in the particular place under observation. Furthermore, even if large numbers of alewives had passed up, there is nothing to indicate that they would have found suitable spawning places, or if they had that the young would have endured the pollution. Shelford ('18) very well indicates, that to all toxic substances the younger or smaller fish, down to the smallest fry, are more sensitive than older ones, and that in one instance under observation the resistance of the egg falls gradually from the time of fertilization to the time of hatching. The point is that "tests of the minimum quantity of poison which will prove fatal must be made on the most sensitive stage; the strength of the chain is the strength of its weakest link."

Again, while the pollution may have been comparatively slight or even absent at the time, there is no evidence that at a corresponding season another year, the pollution would not have prohibited the ascent of alewives.

As concerns sawdust, to which Evermann referred, while the immense deposits of the lower St. Croix River in Maine and New Brunswick apparently did not prevent the ascent of salmon, it is positively known that they could not breed upon sawdust-covered spawning beds.

A stream may be polluted in one part and not in another. This being found to be so in any instance, and having ascertained to what kind of fish the unpolluted portion is in every way suited, it may be stocked, provided measures are taken that it shall not be subsequently polluted. The advice here offered is not to attempt to stock polluted waters. If waste can be diverted elsewhere and the water purified, see that it is done before attempting to stock. It will be economy, with gratifying results.

In addition to pollution to which reference has been made there are conditions which may be called natural pollution. Besides those with which almost everyone is more or less familiar, if he has given any attention to aquatic conditions, such as the generation of noxious gases, etc., from decaying vegetable matter, there is one condition in particular that should be mentioned. It is concerned with acidity of the water. It has been found that bog-water—particularly that of sphagnum bogs, floods after a prolonged dry period, and the last snow freshets of spring are often more or less deleterious to fish. In an instance of heavy flood following a drought, it was found (Richmond, '21) that brown trout were considerably affected, the young fish being most seriously so. This flood water was found to be nearly four times as acid as the normal water which ran during the drought, and was of an acidity intense enough to coagulate the mucus on the bodies of some of the younger fish.

This is only one of the many natural factors which may affect the habitableness of certain waters by fish, but it is one which may be augmented perhaps by deforestation, with attendant droughts and freshets, and may have some significance in selecting "head-waters" for planting trout, even though the water is apparently cold enough.

An important practical study of New York stream pollution has been made by Suter and Moore ('22). In this they have shown, by a series of plates, representative plants and animals from clean water to a severe degree of pollution. They have also compiled a table showing the limits of toleration of fish to various concentrations of pollution. For a general account of the pollution of New York streams see Ward ('19).

Forbes and Richardson ('13, '19), and Richardson ('21a) have made very valuable investigations of "index animals" in their studies of the pollution of the Illinois River, and very recently F. C. Baker ('22) has given special study to mollusks as indicators of pollution. Because of the sedentary habits of these animals they are of special value as an index. These pollution studies have thus given a new interest to the associations of animals found living together in their minor habitats.

Physical Obstructions. The earliest and most decided artificial modifications of area and capacity of lakes and streams were produced by dams. There are but few if any water systems in the United States, however remote, that have not been more or less affected by dams erected for one purpose or another.

By the erection of many recent dams constantly higher stages of water than formerly have been produced, accompanied by some advantageous conditions, perhaps, such as that of enlarged physical or biological capacity. But even in instances where constantly higher levels are maintained there are usually fluctuations due to utilization of the water. There are other instances where the higher level is only temporary and where it may be reduced to below the original or normal level, so that areas above the dam may become practically dry at times. The fluctuating level caused by drawing off the water tends to destroy the marginal vegetation and the fish food organisms living in this shallow water. (Cf. Moore, '23; Osburn, '21.)

The effects of dams may be not only restrictive upon the limit and approximate equilibrium of life, but injurious by more or less obscure interference with the habits of fishes. High stages of water may afford new feeding areas for some kinds of fish, but this signifies only change of locality. Fish are enabled to ascend farther up some brooks and even onto overflowed areas, but since in many instances, the stored waters are sooner or later drawn upon, the possible effects are manifestly serious. A sudden drawing off of the water may not only let out many fish which have congregated above dams, but also seriously affect those which have entered the overflowed tracts and small brooks, often leaving them stranded or to slowly perish as the pools left by the receding water become heated or evaporated. High water of a lake may facilitate the ascent of tributary streams by some species in the breeding season, but it also covers former shoals with excess of water, so that other places of suitable character must be sought, and these may not exist.

If, by chance, fish have become accustomed to temporarily prevailing conditions, sudden changes can only be to their general disadvantage and must necessarily react unfavorably upon the perpetuation of the fish supply.

Dams also interfere with the dispersal of fish as well as with their migrations, by obstructing the passage from one body of water to another or from one section of a stream to another. As has been stated, some species make seasonal movements from one place to another for breeding, feeding, or to meet changing seasonal conditions. These obstructions usually are to movements in one direction only. They often permit a downstream movement but not a return (figures 36, 37). So fish which inhabit a lake or the lower sections of a stream must be very seriously affected. In some cases this may be an advantage, by preventing the invasion of upper waters by undesirable fish.

Depletion of many waters and inability to restock them with certain species may be attributable to dams. In some localities attempts have been made to remedy such conditions by affording a passage past or through the dams by means of a structure commonly known as a "fishway."

Fishways. The construction of fishways for anadromous fishes was one of the earliest measures directed toward conservation adopted by state governments. Laws were enacted requiring the owners of dams to provide fishways and in many instances the fishways were constructed and maintained for awhile to become neglected in later years, and seldom have new ones been made. The law concerning the structures was seldom enforced. One reason for the neglect was that the fishways appeared to do no good. The fish did not ascend them.

Thirty years ago an article appeared in a sportsman's journal (Waters, '91) in which, among other things, it was stated that there was an expensive fishway at Holyoke, Mass., built some years previously at a cost of $30,000 and so far as known no shad, salmon, or blackbass ever got to the top of the stairs. Nothing but eels ascended it. The facts are that many fishways have been faulty in their structure or location. Furthermore, the same type of fishway will not answer for all kinds of fish, and fishways are expensive and difficult to make effective.

When it is proposed to install a fishway in a dam, both an engineer and one who is conversant with the habits of the fish for which the fishway is intended, should be consulted.

For the purpose of restricting fish to certain localities gratings or so-called screens have been in vogue. These structures merit some discussion as sometimes notwithstanding the presence of a screen, stocking has been a failure or the depletion of waters was not checked.

Screens. It would seem that when fish had unobstructed passage to and fro in any waters naturally inhabited by them, a check to natural movements would be undesirable. But some prevention to their passage over a dam or obstruction preventing return would seem desirable. Observations upon the habits of various fishes indicate that they differ according to the kind of fish and the character of the locality in the propensity to go down an outlet of a lake or to migrate from one portion of a stream to another. Some of the reasons for these movements are plainly evident, others may be inferred, and still others cannot be more than conjectured.

Some anadromous fishes, such as the Atlantic salmon, shad, alewives, etc., descend streams both as adults and young in order to go to sea. In some localities only the outlet affords suitable spawning places for certain kinds of fishes. There may be other seasonal movements of some kinds, perhaps for food. Some fish may gain an outlet by accident, in an overflow or flood, others by some unnatural circumstance, such as the sudden opening of the gates of a dam, or by following a log drive, which they have been said to do for the sake of insects dropping from the logs.

If a body of water is overstocked or the water is uncongenial to the fish, a natural exodus may perhaps ensue in search of food or congenial conditions. There may also be irregular, more or less individual to and fro movements of some kinds of fish, for which no definite reason can be assigned. The fact is, so little is known concerning the habits of any species that it is mere conjecture to attempt to explain the movements.

So far as the desirability of screens is concerned, though, the fact that such movements take place usually is regarded as sufficient. The only question is that of the necessity for a screen and its effectiveness when there is one.

The utility and desirability of a screen depends also upon the kind of fish it is desired to prevent going into the outlet, and the conditions obtaining in the body of water for which the screen is proposed, and the character of the outlet as well.

Usually a screen is installed because of a demand from those who fish in a lake, where the results of fishing appear to be incommensurate with the numbers of fish which have been planted in it, and the first thought is that the fish have departed by way of the outlet. Now, screens are expensive, and when one is demanded, the actual necessity for it and whether or not it is likely to be effective should be positively ascertained by investigation. The cause of any apparent depletion, whether by outlet or some other way should first be learned by competent investigation before going to the expense. In one instance known to the writer, a practicable fishway would be more effective in maintaining the stock than a screen. In another a screen erected at the stated cost of $30,000 is absolutely ineffective in maintaining the stock, and unnecessary too, for the nature of the fish concerned is not to leave the lake in considerable numbers except for spawning. In this case if the fish did go into the outlet in numbers sufficient to deplete the lake an effective screen would be justifiable, as the fish having gone into the outlet cannot get back. But that this lake continued to be well stocked before there was even a dam in the outlet indicates that a screen is unnecessary. Furthermore, this particular screen, as is the case with most screens, while it might prevent the egress of grown fish would not prevent the passage of young fish should they attempt to descend.

Another instance is that of a natural landlocked salmon water. In former years the outlet was a famous and favorite fly-fishing resort; and but few fished in the lake. Also the outlet was the principal breeding place for the fish, in fact practically the only one of considerable consequence. The final erection of a new dam with an impracticable fishway, prevented the return of any salmon which succeeded in gaining the outlet. The natural spawning grounds were also cut off. However, the latter was considered of minor importance as for many years the descent of breeding fish had been obstructed by nets and the fish taken for artificial propagation. The apparent decline of salmon in the lake caused a demand for a screen, which has been installed. It prevents the descent of adult fish, excepting perhaps during log drives, but not of the young fish. It is not known that the young go down, but there is evidence that the screen has not produced the desired results.

The fact is that no investigation concerning the alleged decrease of fish, in any of the waters mentioned, has ever been made. If the *cost of the screen in any instance had been devoted to investigation, practical results might have been achieved.*

Stocking and Restocking Problems. A body of water is usually stocked for one or the other or both, of two purposes, namely, for food supply or to afford sport.

No small body of water can afford an unlimited supply of food fish. If a market fishery is carried on in inland waters for sport fish, it is impossible for the stock to be naturally maintained. In many, if not all instances, even considered from the sport-fish side, the stock cannot prove self-sustaining save by rigid restrictions and regulations from the beginning to the end; so rigid indeed that it becomes almost, if not quite impossible to afford satisfactory fishing to an increasing number of anglers, and after all, recourse must be had to outside sources of supply.

It might be possible to so manage large bodies of water that they would afford both commercial and sport fishing, but as a rule each class of fishing must be restricted to different species. As

Fig. 36. Sluice dam on Dead Cambridge River, a fine trout stream near Rangeley Lakes, Maine. An obstruction preventing trout from passing upstream.

Fig. 37. Back water on Dead Cambridge River above sluice dam. Trout may pass downstream when the sluice is open, but cannot get back.

previously indicated, all the interrelations of these different species should be taken into consideration when regulations of the fisheries are formulated.

Successful stocking of waters with game fish depends largely upon the kind of fish best suited to the waters, or rather to what kinds of fish the waters are best suited. In other words it is necessary to determine what kind or kinds of fish will likely produce the best results in quantity and quality as game fish.

Individual anglers have their favorite or preferred game fishes; but it does not follow that the water which they or their associates of kindred taste wish to stock will yield the desired results if the particular favorite is planted. The desired results from planting any kind of game fish are fish of satisfactory size, in sufficient numbers to afford good fishing for all who fish that particular water.

As stated elsewhere, all waters are limited in their capacity to support fish. Other things being equal, a large body of water will support more fish than a small one. A large body of water, too, is capable of supporting more kinds of game fish than a small body of water, which fact is due to the usual diversity of conditions or variety of habitats in a large body of water. Any body of water will support a number of kinds of fish in a quantity directly in proportion to the capacity of the suitable conditions for each kind.

In his address to the American Fisheries Society in 1893, President Herschel Whitaker said: "Much has been done in the past few years in attempts to successfully introduce into our waters foreign species of fish, and while these efforts should not be too hastily criticised, it may be said that outside of one or two varieties thus introduced, this work has not been successful. The experiments have been of but little practical value when we count results. It must appeal to the average judgment, after all, it would seem, that if an equal amount of effort, time and means had been devoted to the increase of the native fish which we have that are deserving of care and attention and multiplication, the money, time and effort would have been more practically spent. These indigenous fish are natural to our waters, are of excellent character; it is no experiment to determine whether they will live and thrive. They do not require to be adapted to strange conditions and new surroundings. Is it not better practical fish culture to increase the good varieties that we have than to go far into the field of experimentation? It would seem that the office and function of a fish commission is best fulfilled when it gives attention to the increase of those fish natural to our waters, rather than attempt to solve unsolvable or difficult questions which have but little practical value."

The principle conveyed by the foregoing quotation is good. It is the one which should have been followed from the beginning, but which has not been strictly followed even since the address was delivered. The consequence has been that in many instances both the native and introduced fish have failed to afford the desired results. This has been discussed in the foregoing pages. There are also instances where introduced fish have supplanted the original fish. Sometimes this supplantation has been because the conditions were best suited to the introduced fish and the native fish would never have amounted to much in that particular water. Sometimes the ascendency of the introduced fish is attributable to the direct effect of the voracity of that form, and the decrease or disappearance of the native fish is chargeable to the same factor, that is, the first has eaten the other. More often the effect of the voracity of the introduced form is an indirect one, that is, it becomes a competitor for the food supply in which its voracity and activity gives it an advantage. Occasionally the supplanting has been with a fish superior to the native fish, but more often one which in its new environment becomes inferior in one or more ways. There are instances of waters, originally containing no game fish whatever, which by the same haphazard "experimentation" have proved eminently suited to one or another fish. More often the experiments have sooner or later resulted in failure. Some of the failures may be attributed to unsuitable waters, to improper planting methods, or perhaps to too small numbers planted to offset inevitable natural loss.

It has occasionally happened that acclimatization has been effected, not in the immediate waters where the fish were planted, but in some other portion of the water system. In such cases it is unnecessary to say, the fact is attributable to more suitable waters in the one than in the other place. Such successes as these are due largely to chance selection of suitable water and often repeated introductions.

It is natural to believe that waters which have been depleted of the indigenous species could best be stocked by the same species that originally inhabited them. If the fresh waters of the entire State had to be restocked with fish, the logical species would appear to be those of general distribution in the State, but it does not necessarily follow that the original inhabitants of a given body of water are best suited to it, or rather that others will not thrive there as well as the original inhabitants, or even better.

Usually there are more or less restricted localities which are ideally adapted to fish that do not occur there, and are less or even ill-suited to the fish of general distribution in that body of water. For instance, because fish which are common in the lower course of a stream occur to some extent in its upper course, it does not signify that some other kind would not thrive or even do better than the originals in the latter locality. Or the reverse may be the case.

By various means the original conditions of some waters may have been so modified that they are no longer suitable for the species originally occurring there, but still may be suitable for some other species. Mr. Whitaker was right on general principles, but circumstances alter cases. Where a body of water, lake or stream is depleted but still inhabited by indigenous fish which are all that could be desired or expected in food and game qualities, the cause of depletion should be ascertained, and if changed conditions are not the cause of depletion the natural stock should be restored. In the other instances mentioned the logical thing to do is to ascertain to what kinds of fish the waters are best suited and act accordingly.

Problems of stocking and restocking of waters must be considered from at least two and probably three different angles: (1) Is it the intention to make the body of water entirely self-supporting and the fish self-sustaining? (2) Is it intended to make annual plants, and depend upon them alone for the fishing? (3) Is it expected that the products of natural propagation shall be reinforced by annual plantings of fish?

There are certain requisite conditions for each of these propositions. In the first there must be a permanent and adequate food supply for all ages of fish from the time they begin to feed until they cease to do so. There must be spawning places of adequate area and suitability. These are the principal points for consideration. All others hinge on them, for in a body of water otherwise of eminent suitability, but lacking in either one of these essentials, the stock cannot become self-sustaining.

In the second proposition, in a body of water, if otherwise suitable in every way, spawning places are not a necessary consideration, and the stock may be maintained by regular plantings every year with enough fish to take the place of those removed, or dying from natural causes. But this is an uncertain and expensive procedure.

An extreme example of this sort of procedure — extreme in that a food supply had to be introduced also — is one related by "Billy" Keil ('22) concerning "Salmon Fishing in Sterling Lake." Sterling Lake is a small body of water, according to Mr. Keil about 1½ miles long and a mile wide, situated on the E. H. Harriman estate. It is stated that it carries an average depth of more than 75 feet with a maximum of 126 feet. It has no tributaries and the general character is rocky with the exception of a sand beach at the northern end. Mr. Keil regards it as a spring-fed lake, in fact, virtually itself a spring. It is related that in 1887 Alpine saibling from Europe were introduced and subsequently a few were caught and some were observed for a few years in the lake, then they disappeared. In the late seventies it seems that lake trout had been introduced and apparently "thrived" for a time and produced fair angling. To the lake trout Mr. Keil attributes the disappearance of the saibling. Finally the lake trout disappeared, due to "lack of food, with its resulting cannibalism." In 1903 Mr. Keil restocked the lake with 30,000 fingerling lake trout and he states that for about ten years following this plant excellent angling for these fish was to be had by the few individuals fortunate enough to obtain a permit to fish this water. "It was not unusual," he says, "for an angler to take four or five trout, averaging 7 or 8 pounds each, in a day's fishing, though from the size of the fish taken it was plainly evident that if natural reproduction was taking place (as no doubt it was) none of the resulting progeny were escaping the voracious maws of the mature fish. From 1913 to 1918 not over a dozen in all of these fish were taken, most of them old specimens and none in very good physical condition."

In 1918 Mr. Keil was engaged by the Midvale Company, who had leased the property, to make a thorough examination of this lake, and to report upon the possibility of building up and maintaining good angling. He says: "A careful limnological investigation showed that *with the exception of food and spawning grounds* [italics the present writer's], every other condition (both physical and biological) was well suited to either the ouananiche or the steelhead trout or both. The lack of spawning grounds, of course, could not be remedied, as both of these varieties require good sized running streams for reproduction; but as long as we would have to depend on annual restocking to keep up a good supply for fishing, this was of little consequence. It was found that an ample food supply could easily be built up by the introduction of suitable food fishes, for the water was swarming with the microscopic crustaceans upon which these small food varieties subsist."

Mr. Keil goes on to say that in the spring of 1919 smelt fry to the number of 3,000,000 were planted, and on the 29th and 30th of the following October 2,102 steelheads and 1,264 landlocked salmon yearlings, averaging about 8 inches in length were planted. Again in 1920, 3,072 steelhead and salmon yearlings from 6 to 9 inches in length were turned out. In the spring of 1921 there were planted 3,000,000 smelt fry, and in the fall approximately 3,000 more steelhead and salmon yearlings. Mr. Keil reports that in the summer following the introduction of the trout and salmon, many of these fish were taken, weighing as heavy as 2 pounds. "With the opening of the season of 1921 wonderful reports began reaching us of the big fish that were being taken."

In the middle of June Mr. Keil landed four landlocked salmon running from 2½ to 4 pounds. Later in the summer he secured a steelhead trout which weighed 4½ pounds.

All of these fish, according to Mr. Keil, were gorged with smelt, and "their rapid growth and splendid condition is an illustration of what can be accomplished by the proper building up of a suitable food supply before desired game varieties are introduced."

From what Mr. Keil says it is quite evident that the fish that were caught, whether lake trout, saibling, steelhead trout or landlocked salmon, were simply grown-up individuals from the original plants. Furthermore, it is more than probable that the food supply will need to be annually replenished also, for there appear to be no suitable spawning places for the smelt.

Such procedure is not reconstruction or conservation, but simply fish farming, akin to raising pheasants on a private estate to be shot by the owner and his friends in the fall. This may be all right as a private venture by those who can afford it, but where public money in concerned it would amount to extravagant waste.

The stocking of certain waters with non-indigenous species has already met with an unforeseen serious result. This result was possible of prediction, in fact it was predicted by the present writer in connection with one lake and one species of fish several years before it became manifest. The danger of such a result was not recognized by those engaged in fish cultural distribution. In the case of other species in other waters such fish cultural procedure has already culminated in so serious a condition that unless radical corrective measures are soon adopted the question will surely arise as to whether in these instances, at least, fish culture has not proved a curse rather than a benefit. For it certainly signifies the not very remote extinction of the species concerned, and in time cannot but involve all species continuously subjected to similar fish cultural operations.

In a foregoing paragraph pertaining to indiscriminate distribution of fishes, reference was made to unsatisfactory results from the distribution and stocking with chinook and landlocked salmon. A few years ago, to meet the objections of those who favored the continuous planting of landlocked salmon rather than chinook salmon in eastern fresh waters, the advocates of the latter fish claimed that landlocked salmon eggs were not available in sufficient quantities, whereas the chinook eggs could be obtained in large quantities.

Why couldn't landlocked salmon eggs be obtained in sufficient quantities, since they had previously been plentiful enough to send broadcast all over the country and to foreign countries for stocking purposes? There can be but one answer, the failure of the source of supply. It has already been noted that in 1919 chinook salmon hatching and planting was abandoned because of inability to get their eggs in sufficient quantities. The reason is evident, namely, the decline at the source of supply in the Pacific Coast rivers.

This is a case where the combined natural and fish cultural production is out of proportion with the take by the fisheries, so retrenchment in egg distribution becomes necessary in an effort to make up the deficiency caused by the fisheries.

The original sources of supply of landlocked salmon eggs were limited in extent and the stock of fish was consequently also limited. But compared with the fisheries the fish were relatively abundant, and provided a supply of eggs and young fish which were widely distributed, as previously stated, but at the same time a certain proportion of the products of fish cultural propagation were returned to the waters from which they were obtained. This proportion was regarded as sufficient to maintain the stock, the view being based upon the unproved opinion that it was in excess of the number which would have reached the age at which the fish were planted, had they been hatched under natural conditions.

Notwithstanding the "liberal" return to the native waters, there has been a continuous though fluctuating decline for some years, and as previously indicated, curtailment of egg shipments became necessary a number of years ago, and at the present time it seems that very few if any landlocked salmon eggs are permitted to go out of Maine. Yet the indiscriminate distribution is said to be continued within that State, notwithstanding the fact that the original sources of supply appear to be failing and the great majority of other waters stocked are evident failures. Outside of Maine there are practically no landlocked salmon waters left of those so intensively stocked in past years, and absolutely none remains with a self-sustaining stock.

For a number of years there has been complaint by anglers that salmon fishing in one of the most famous original landlocked salmon lakes was going bad, notwithstanding the operations of the State hatchery. A notice apeared in one of the papers to the effect that it was proposed to plant " Canadian Sea Salmon " there, apparently to offset the decline of the native salmon. This announcement elicited remonstrance from several persons interested in that lake. An article of this kind having attracted the attention of the Commissioner of a neighboring state, who had also thought of importing the Canadian fish to remedy the unsatisfactory conditions in the water of his state, wrote the author: " At the present time, it is, so far as I am able to learn, impossible for us to get any great amount of real landlocked salmon. A few years ago attention was turned largely to planting western chinook salmon in our waters. They are certainly sea-going fish, as much as Eastern or Canadian river salmon, with the added drawback that their life is short and their reproduction is limited.

" There is no need for me to elaborate on their habits, which you know better than I, but I am discouraged in trying to create a permanent fishery by raising them. We are endeavoring to get all the eggs possible from the salmon taken from our lakes, that is the Eastern variety, but for the past few years we have at no time secured over 70,000 eggs, which is a very small amount compared with what we would like to have.

" I find that it is now possible to obtain the Eastern Canadian River Salmon from the Canadian Government, and it certainly seems to me that our chances of success with these fish are as great, if not greater than with any other species available. Is it not probable that while a percentage of these fish when planted will find their way back to the sea, as large a percentage of them may be expected to remain in the waters? Would not our chances of success with them be greater than with the Western Salmon and while I personally should very much prefer to raise real native landlocked salmon, does not the fact that they are not now available in any adequate numbers make it advisable for us to try the Canadian fish?"

The situation in that State and elsewhere is as follows:

In the first place no effort was ever made to ascertain whether the quota of young salmon annually returned to native waters was in excess of those which would result from natural reproduction. No attempt was made to ascertain the cause of the decline.

Stocked waters elsewhere failed because nowhere was a self-sustaining stock produced. Had the life history of the landlocked salmon been thoroughly learned and the lesson heeded the present situation might have been obviated.

Much money and energy had been expended in trying to acclimate the salmon in other waters. The hatcheries on original waters failed to maintain the natural stock in those waters, and the same obtained in the case of most other waters. Those which have not already failed are failing. Still, in some localities it was thought that the problem of salmon fishing was solved by the introduction of chinook salmon. This venture failed. Then it was proposed to take a chance with Canadian sea salmon.

How inconsistent such measures seem, when it is seen that years of fish cultural operations on original waters failed to maintain the stock! If fish culture could not accomplish that with an indigenous species under conditions naturally favorable to the fish, how could it be expected from the introduction of non-indigenous forms the habitats and natural habits of which are so different from the landlocked salmon?

If a self-sustaining stock had been produced, as it might have been, in certain places, and had the matter received proper scientific attention, there would now be no stocking problem. As the situation now appears to be, the source of the egg supply bids fair to be exhausted and there is no effort made to prevent it. So in all cases where adequate breeding and food conditions do not exist, temporary successful introduction is marked for failure as concerns some of our most esteemed game fishes.

The egg supply of the chinook has practically failed; the supply of landlocked salmon eggs is nearing complete failure; steelhead eggs will ultimately fail at the source unless preventive measures are early put in force. The same may be said of the Canadian sea salmon. The "rainbow trout" is in almost immediate danger. This form will be discussed more in detail later. Even now much of State and Federal brook trout culture is largely dependent upon private trout breeders for the egg supply.

There is but one preventive remedy, but it is a comprehensive one. The first step is to cease to rob Peter in order to pay Paul, and another is to make scientific investigations, taking into consideration every factor concerned.

The third proposition, however, may apply to waters having limited spawning places, but otherwise capable of supporting more fish than the natural breeding would supply. In such instances, annual plants of young fish may be made to help maintain the stock to a satisfactory point of production, that is, satisfactory fishing, if properly regulated. Such situations are probably the most common today.

Some rather commonly observed facts in connection with waters which previously have been naturally or artificially stocked are those of deterioration in size and decrease in number. Such observations may be classified somewhat as follows:

1. Decrease both in size and number.
2. Decrease in size but not in number.
3. Decrease in size and increase in number
4. Decrease in number but no decrease in size.
5. Decrease in number and increase in size of those remaining.

When one or another of these phenomena has been observed, very often the opinion of scientific authorities has been sought. Not infrequently, however, the cases have been diagnosed by the observer, without any consideration of past or present conditions other than those immediately observed, i. e., the decrease in size or in number of the fish. Usually, even when the deterioration in size and decrease in numbers are concerned, the explanation of the one fact is in no way related to that of the other. Deterioration in size has often been attributed to "inbreeding," whatever is meant by that term in connection with such cases. The remedy usually recommended has been "new blood." In such explanations, presumably "inbreeding" signifies that the fish have become physically and physiologically "run down" from breeding in comparatively limited numbers. But it does not appear to be recognized that fish have naturally existed for years in some waters and bred together in even smaller numbers without deterioration and that in some other localities fish have actually increased in size as the number declined.

In "Modern Fish Culture," Mather ('00) says that with fowls and the cattle on the farm there is danger of inbreeding because the parents, especially the sires, are so few. But he adds, "There was no such danger among the herds of buffalo and there is none among the trout in confinement. Take the eggs from 2,000 fish and fertilize them with the milt of 1,000 males; turn the progeny loose and breed from them two years later, and what are the chances of mating brother and sister?"

The migration view seldom is supported by any evidence, nor is any reason suggested as to why after residing in a lake for a number of years, the fish should finally decide to change their abode. Such an explanation is particularly illogical when applied to the decrease of indigenous fish which have existed in a lake for untold years. The commonly accepted view that indigenous fish permanently vacate a lake or stream, has led to the unnecessary and therefore wasteful expense in the erection of screens in an effort to prevent the migration.

Undoubtedly when possible, fish will leave unfavorable for more favorable conditions. This fact simply emphasizes the necessity of ascertaining the conditions before introductions are made.

That the decrease in numbers of fish may be attributed to their having been devoured or destroyed by one or another natural enemy, when such enemies are present in the same body of water, is an explanation which it is claimed, is based upon known facts. But in many cases in question the facts have not been verified.

It is known, for example, that pickerel subsist largely upon fish and that they have always been adjudged as notoriously ravenous. When a body of water once containing both trout and pickerel has become depleted of trout the pickerel is accused of being the direct cause of the depletion. Very often the depletion of trout may be more justly attributed to the greed of man than to the voracity of pickerel. Voracity is characteristic of all predatory fishes, and in the case of fish-eating fish "voracity" is a relative term, much depending upon the size of the fish and its opportunity to display that characteristic.

The deterioration and the decrease in numbers of fish will be discussed as follows:

1. Concurrent decrease in size and number of fish may be due to one or more of several assignable causes.

In many instances the apparent decrease in size may be attributable to over-fishing, especially in a comparatively small body of water. To attain a large size the fish require time in which to grow, and persistent intensive fishing tends to lower the size standard by continuously removing the larger sizes, so that sizes previously regarded as small come to be the maximum size attained.

If a size and quantity limit is strictly observed in the fishing (which is seldom the case) the coincident decline of size and number may be due to decrease of food supply, and cannibalism.

There may be other factors than those mentioned which are operating independently. Whatever the cause may be, it can be positively determined only by competent investigation.

2. Decrease in size with no decrease in number may be attributable to one or the other of two common causes. One is that of reduced food supply. The other is that of the larger fish having been caught before they have had time to attain a large size. But the most common cause is likely to be found to be that there are too many individuals compared with the amount of food for them. In other words there is lack of balance.

3. Decrease in size with increase in number may be attributable to inadequate food supply and exceptionally favorable breeding conditions, with freedom from enemies, or it may be a case of overstocking.

4. A decrease in number with no decrease in size, suggests as a cause over-fishing and unfavorable breeding conditions.

5. A decrease in number with increase in size suggests over-fishing or other destructive agency, with no diminution of food supply, so that the remaining fish are well fed. Or, if the water has been artificially stocked, that the existing fish are merely survivors of the original plants, and that they have not reproduced, at least not extensively enough to maintain the stock.

It has often been noticed that following the first introduction of some kind of fish in a body of water their growth is rapid and they attain a large size in good numbers. Later it becomes evident that the fish have quite generally fallen off in size, or newly planted fish do not grow as rapidly or attain the size of those first planted.

Such instances have been many, and have led the fish commissioners, the fish culturists, or the interested public, to attribute the facts to various causes other than the real one. Or, it may be that while the cause was obscure, or without any consideration of the possible or probable cause, the situation being unsatisfactory, there is a demand for some other fish. If the Commissioner did not comply with the demand, the new fish were sooner or later secured by first getting a new Commissioner. In a few instances the new fish appeared to be the solution, for it waxed great in size and was sufficiently numerous to be pointed to with pride in the Commissioner's reports. However, subsequent reports ignored the fish, or gave it only passing mention, for the reason that it was merely a repetition of the condition exhibited by the first mentioned fish, with the added fact, perhaps, that some other inhabitant of the waters was exterminated.

The size attained by any species depends largely upon the quantity and quality of its food supply, and having sufficient time in which to grow. In the same length of time, other things being equal, some species attain a larger size than other species do. In other words they grow faster. The number of fish that can be produced and maintained hangs on the favorableness of the waters in every way, the number planted, and the number removed. When a body of water is stocked to its maximum limit, only a comparatively few will attain a large size.

It is self evident that a limited body of water cannot afford an unlimited fish supply for an unlimited number of anglers, which judging from some operations, seems to have been thought possible. Every body of water is probably capable of being made to support more life than it did in a state of nature, but any attempt to make it do so is attended with danger. It must be intelligent action, based upon exact knowledge.

In an article by R. L. Barney and H. L. Canfield ('22), a statement is made which applies to natural waters as well as to farm fish-ponds: "The tendency in stocking new ponds or in restocking old ones seems to be toward overstocking. Evidence discussed herewith suggests that, for a pond to gain production of edible-sized fish and still contain a regular large annual production, it must not be overstocked." And, again, a note in "Fisheries Service Bulletin" (U. S. Bureau of Fisheries, March 1, 1923, No. 94), referring to production of the Fairport Farm Pond, says: "It has been observed that too great a production of young fish in a given year prevents many of the half grown fish from attaining edible size through too serious competition for the available food."

Overstocking may be effected in two ways: (1) by introduction of too many kinds of fish, and (2) by planting too many fish of any kind.

Before stocking a body of water, it is necessary to ascertain the actual conditions, both favorable and unfavorable, and to determine, to use a life insurance term, "the expectation." We may judge, if a stream or lake has supported certain kinds of fish, that, the conditions being unchanged, it is again capable of doing so. However, careful consideration is required to make sure that the conditions have not changed and to reach a positive or exact decision respecting the number of individuals the water will support, or, if the conditions have greatly changed, to ascertain to how many and to what kinds of fishes the waters are adapted. In this connection, it should be stated that because certain fishes appear to be of no utility as food or game fish, or because they are predacious fishes commonly designated as fish enemies, and of little value for food or game qualities, it does not signify that they are useless in the waters inhabited. This is a matter that should also be determined.

Natural Enemies of Fish. The so-called natural enemies of fish are many and various, almost all zoological as well as some botanical classes being more or less represented. Bacterial, fungous, plasmodial and parasitic diseases destroy them individually and epidemically. Non-parasitic, as well as parasitic worms and crustaceans and some insects are not infrequently fatal. Among the vertebrates certain fishes, batrachians, reptiles, birds and mammals can be mentioned. Of these the predacious fishes are generally regarded as the most serious.

The normal enemies of any fish, under natural conditions in a given body of water, have probably existed in normal numbers until civilization interfered with natural conditions. These so-called enemies are nature's balance wheels and it is only when normal conditions are disturbed that those enemies of any fish become generally harmful to it. Man has been the most destructive enemy of fish in general. He has tampered with nature's machinery and thrown it out of balance. The results have not always been correctly attributed to him, but rather laid at the door of some of the alleged natural enemies.

Man's interference may have increased the number of some enemies and diminished the number of others. Some one natural enemy of a given fish may prey upon other fishes as objects of his "enmity." Some of the latter may also be enemies of the first mentioned fish; sometimes direct enemies, that is, preying directly upon the fish, or competitors for the food supply, or both. In the latter case their injurious effects would be doubled. So if man should destroy the first mentioned enemy which serves as a check to the undue increase of the others, the effect of an over-production of the latter might be worse than before.

There are many well-known instances of lakes and streams, which have been stocked and restocked, but which have shown only brief periods of satisfactory fishing, or none at all. In such instances the most common remedy suggested for the condition has been the extermination of one or another fish alleged to be an enemy of a more highly esteemed fish. Whenever this has been accomplished the desired or expected results have seldom been attained.

Let us take a specific example. In the report upon the investigation of Lake George, elsewhere cited, Mr. Titcomb said: "within the past twenty years at least thirteen distinct species of fish have been planted in the waters of Lake George, and some of them in very large numbers. There has been more special legislation for the protection of the fishes of this lake than for any other body of water within the State. Notwithstanding these facts, anglers report that fishing conditions are not as good as they were some years ago, and this appears to be especially true with reference to the lake trout which may be regarded as the most important food fish inhabiting the lake."

Dr. Needham suggests that "four native species, namely lake trout, small-mouth blackbass, yellow perch, and bullheads, are the ones to be fostered and encouraged as being perfectly adapted to the conditions of the lake; and these should be rigidly protected during their respective spawning seasons. While the northern pike is highly prized by some, it is not worthy of propagation or protection *because of its voracious fish-eating habits.*" (Italics the present writer's.) Recommendation 4 is: "that the law for the protection of great northern pike or 'pickerel' be repealed."

Dr. Needham says that undoubtedly the most extensive and exclusive fish eater in the lake is the northern pike or "pickerel" but that no studies of pike food were possible at Lake George because *the stomachs of all but one that were examined were empty.* He stated, however, that the records of examinations extending over many years at Cayuga Lake showed them to be almost exclusively fish eaters. In another place he says: "the pike should probably hardly be considered an enemy of the lake trout, and perhaps not even a serious competitor, for it keeps to surface haunts and hardly invades the grounds of the trout in deep water. But it certainly is both an enemy and a competitor of the shore fishes; doubtless it eats mainly herbivorous shore fishes like shiners, that are most easily captured; but it doubtless eats the game fishes as well when it can catch them."

Superficially considered, a fish sometimes appears to be "his own worst enemy" in that it is addicted to cannibalism. In some instances it is very probable that fish eat their own kind because they are driven to it by starvation. But there are several known instances of fish devouring the eggs of the same species on the spawning beds. Trout, salmon, whitefish and others have been observed to do this habitually in some localities. In the cases of trout and salmon it is stated that it is usually the young fish which lurk around the spawning beds looking for fresh eggs. But in the case of whitefish the present writer once found gravid as well as spent female whitefish with their stomachs distended with whitefish eggs (Evermann, '05, p. 103–104).

There is a great need for careful study of the food habits of fish eating birds. Two authors who have discussed this subject are Warren ('97) and Taverner ('15), the latter describing the salmon eating habits of the double-crested cormorant. The kingfisher, although frequently condemned, has never been carefully studied.

The parasites of Oneida Lake fishes have received preliminary study by the N. Y. State College of Forestry cooperating with the U. S. Bureau of Fisheries (Pratt, '19, '19a, '23; Van Cleave, '23). The problem of these parasitic diseases deserves much more attention than it has received in the past.

Fish Planting In Public Waters. Mr. W. C. Adams of the Massachusetts Commission says it is a common experience to find that in spite of the good intentions of the receivers, many consignments of young fish, which have cost money and great labor to rear, are entirely wasted through improper planting.

Long before this a former State Fish Culturist of New York wrote (Bean, '16) that as a rule the special care given by the State Commission ceases when the cans of young fish are delivered to applicants on the platforms of the railroad stations. "In many cases," he said, "the lack of special knowledge and experience on the part of those who transport the cans to the streams and do the actual planting results in great loss. Thus certain waters that have been stocked with thousands upon thousands of fry and fingerlings during a long period of years still produce, for one reason or another, very indifferent, if any fishing."

Failure for so many years cannot be attributed alone to those who have received and planted the fish. The responsibility for this to quite a degree rests upon a system which acts blindly, trusting to chance in such matters. We have seen that these defects are largely operative even today.

The principal fault was lack of knowledge concerning the conditions obtaining in the waters in which the fish were planted, whether the waters were suitable for the fish, and other facts which should have been taken into consideration. While many young fish are lost through improper handling and planting the most potent cause of unsuccessful stocking is the lack of favorable conditions for the fish. Such conditions differ in relation to the size or the age at which young fish are planted.

Fry or Fingerlings. Opinions differ concerning the age at which young fish should be planted. Some fish culturists advocate fry, others, fingerlings, and still others, older fish. Each exponent supports his view with valid evidence. Bean ('16), in favor of fry planting, said that all the different states and the United States distribute fry, and their experience has demonstrated beyond question that fry planting can be made effective; that prejudice against fry can usually be traced to improper planting methods, or unsuitable streams, and that it should not be forgotten that nature herself plants fry exclusively. Some claim that more fish will grow to maturity from several thousand fry than from a few hundred fingerlings, as in hatchery produced fish the instinct of self-preservation is developed better and sooner in fish planted at the earlier age. Another argument advanced in favor of fry planting is that of the attendant difficulties and expense of raising and handling older fish, and that fry can be transported and distributed in a greater number than is possible with fingerlings or older fish. However, in favor of older fish than fry, it is quite generally admitted that the older a fish is the better able it is to take care of itself. Concerning these points it should be borne in mind that "circumstances alter cases."

The report of the Conservation Commission of the State of New York for 1919, concerning trout, says: "Although there is a great difference of opinion as to whether the best results are obtained by planting 5,000 sac absorbed fry or, for instance, 250 four-inch fingerlings, experienced fish culturists are inclined to favor the planting of 5,000 fry, providing it is possible to distribute the fry in the headwaters of spring rivulets tributary to the stream which it is desired to stock. Spring rivulets may be found tributary to nearly all good trout streams. They may vary in length from one or two miles to a few feet. In width they may vary from six inches to two feet, and in depth from one to six inches. The number of fry to be planted in such rivulets depends very materially upon the length of the stream, and the prevailing abundance of food. Few persons have opportunities to study the food conditions, and it is accordingly safe to generalize by the allotment of 5,000 fry to each mile of spring rivulet, with the understanding that special care will be taken to scatter the fry the entire length of the rivulet by planting a few at frequent intervals with a dipper.

"There is an important argument in favor of planting fry, namely, the instinct of self-preservation, which is developed better and sooner at the time of sac absorption, when the fry instinctively seek natural food. The planting of fingerlings late in autumn, when the water is very cold, is to be discouraged, for the reason that after being trained to receive artificial food several times daily for a period of several months, if planted in these cold waters, which are almost devoid of food, fish which have been accustomed to seek food under natural conditions become weakened from starvation and are an easy prey to any fish of larger growth inhabiting the same waters.

"Small fingerlings properly planted the latter part of May or during the month of June, reach the waters it is planned to stock at a period of the year when there is far greater abundance of minute animal life. The natural food upon which they feed then exists in greater abundance than later in the season when the larger fingerlings are planted. The results obtained from planting twice the number of two-inch fingerlings than can be furnished of four-inch fingerlings two or three months later will accordingly be in favor of the two-inch fish."

Some fish culturists also regard it as more economical to plant fry than to raise the fish to a larger size. This may be true so far as the immediate pecuniary considerations are concerned. But if an undue proportion of the fry perish after planting, the apparent saving in immediate outlay of money is a delusion, for the operation in an effort to perpetuate the stock by planting large numbers in any waters, in the long run is costing far more than is saved by the actual lessened expense of planting at the fry stage.

"The chief argument against planting of fry that has been offered is that they are less able to withstand unfavorable conditions than are fingerlings, and many applicants for fish have not been trained to give the planting the attention which it requires. The Commission is accordingly devoting much attention to systematic educational work among the applicants with a view to better planting, and meanwhile is continuing its efforts to increase the output of fingerlings." (*Loc. cit.*)

From the foregoing it is seen that the policy of the Commission as well as views of individuals vary from time to time. It is the failure of nature to maintain the supply of fish demanded today, which has given rise to the question of how best to meet the demand, and the difference of opinion concerning at what age the young fish can best be planted. The character of the habitats or places where the different stages of young fish live, as well as of adults, varies with the species of fish as do their habits in relation to the conditions under which they live. Nature selected the habitats and they are naturally the best possible places and conditions, else the species would not have survived.

The life histories and natural habitats of some kinds of fish are so well known that it is comparatively easy to decide at what age, when, where and how they should be planted. But there are others concerning which little or nothing is known in the direction mentioned. In the latter case it is obvious that results will always be uncertain until the unknown facts are learned. As remarked elsewhere it is a waste of time, money and good fish to plant any kinds before they have attained an age concerning the needs of which there is definite knowledge.

Aside from the question of economy in raising and transporting young fish, the character of the locality to be stocked and what is known concerning the life history of the fish to be planted become determining factors in deciding the best age at which to plant the fish. Other things being equal, the food and feeding habits of young fish are of first importance. In a general way the natural food of adults of the common species is known, but upon what some of the same fish subsist in the earliest periods of their lives is not definitely known. Although this is so, as concerns waters naturally inhabited by a given species, or waters in which it has become permanently established, the food for all ages of that species must be present in the habitats of the fish at the respective ages, or else the fish would not occur or have been established there. Therefore, if the habitat of fry is known and the habitats of the older young fish are unknown the logical age to plant the fish is as fry, other things being favorable. So with the older fish.

In the case of fry, if it is necessary to plant fry and the natural spawning places of the species are known, it is a justifiable assumption that, other things being equal, the best places for planting them will be on those spawning places, for there is where nature plants fry. If it is known that fingerlings naturally occur in certain shallow water localities, or in deep water, or at the surface at a distance from the shore, those would appear to be the natural places in which to plant the fingerlings. Again the same may be said of older fish.

The object of planting the fish is to supplement the native supply or make up for a deficiency in natural production. In this connection it should be borne in mind that from the time, at whatever age, the fish is planted, nature takes her course, and the only advantage attainable lies in the greater number reaching maturity than would result from the natural process. So by planting fry on the natural spawning places, or older fish in their natural habitats, the only gain attainable lies in the greater number planted than would have hatched naturally from the same number of eggs deposited by the parent fish in the spawning places, or in the case of older fish would have resulted naturally from that number of naturally produced fry.

As elsewhere suggested, the question here arises, are the spawning places capable of supporting more fry than would hatch naturally? They are, of course, other things being equal, if the natural supply of parent fish has been reduced. In this case the question concerning the extent of reduction arises; also the number of fry to supply the deficiency. The same reasoning may be applied to fingerlings, yearlings, etc., in their respective habitats. To exceed those numbers in the final production of adult fish, might result in disturbances of natural conditions that would give rise to worse conditions than those which the artificial planting is intended to correct.

When to Plant. The season of the year when young fish should best be planted has been a much discussed subject, and there has been more or less diversity of practice. The season would seem to depend to some extent upon the kind of fish. However, the natural habitat of the fish at the age to be planted being known, it would appear to be a logical procedure to plant the fish approximately at the time they are known to appear naturally in those places. However, the differences in time of hatching and rate of growth of hatchery-raised fish may be a matter to be considered in this connection.

While, as has been stated, there are many facts and factors to be considered in selecting the places in which young fish are to be planted, there is one of prime importance, and that is the food supply for the young fish.

Food Supply. In the words of a former United States Commissioner of Fish and Fisheries (H. M. Smith, '16), "our knowledge of the food of fishes is as yet seriously inadequate. The food taken by fishes varies with the species, with size and age of the fish, with the season of the year, and with the abundance of the various kinds of food material present in different bodies of water. A few observations in one locality or at one season of the year afford no criterion for the conclusions that we may seek to draw, for an appraisal of the possibilities of fish production in a body of water, for an understanding of the variations in the sizes attained by a given species of fish in different bodies of water, and for the direction of our efforts to promote an abundant and reasonably constant supply of food under all conditions subject to control."

Other things being equal, the statement is likewise true that "barring enemies and artificial hindrances to increase, such as overfishing, fish will multiply up to the limit of the food supply, but cannot overstep that limit. If the food supply can be increased, an increase in the number of fish will naturally follow." (Pieters, '01, p. 59.)

These facts have been long recognized by those who have given the matter of fish culture any intelligent thought. But it is remarkable how little attention has been given to the food of fishes. In a general way the food of the adults of the commoner species is fairly well known, but very little is definitely known concerning the food of the young of many even common forms. Over forty years ago, a "pioneer fish culturist," Seth Green, said that one of the principal precautions to be regarded in stocking streams was not to put in too many fish, and that the food supply of the fish must be considered. Again, one year later, he stated that the secret of successful stocking of waters with fish was in putting the right kinds in waters suited to them. These facts are now as emphatically true as they were so many years ago, although they have always been more or less disregarded. It is not such a simple thing as it might seem to determine to what species of fish a given body of water is best suited, but in a general way, certain conditions being known, it may be inferred that the water will or will not support certain kinds of fishes. However, in fish cultural practices of the past, such inferences have been based largely upon conditions pertaining to adult fish, and little or no attention was given to the matter of food supply of young fish after they left the hatcheries, and even today too little consideration is given that point in stocking and restocking natural waters. For years there has been much discussion concerning places in which to plant, the season in which fish should be planted, and the food of young fish in the hatcheries.

It seems to have been assumed that the young fish could find its natural food abundant anywhere at one or another season of the year, but until comparatively recently no investigation was made to ascertain what constituted the natural food for various ages of the different species, or whether suitable natural food at any time was sufficiently abundant to supply the number of fish planted. The number planted often depended upon the amount of stock on hand and the "pull" of the applicant.

It has been generally assumed that youngest stages of most carnivorous fishes subsist upon the minute organisms, such as water fleas, etc. This assumption is based upon observation of a few species only. It is now known that the food of some species consists of such minute life. A few scientists have made a specialty of the qualitative and quantitative study of the lakes and ponds of various localities.

Although much data pertaining to these subjects have been accumulated and published, usually in technical form, with few exceptions they have been correlated with the habits of young fishes only in a very general way. This fact is due to the lack of trained investigators able to devote themselves to such work. Those who have contributed to the knowledge in this direction have usually been college professors and students who have done so with little or no pecuniary remuneration.

Plantings. The foregoing pertains to planting fish in waters where the fish occur naturally or have become established from previous introduction. In planting fish in waters not previously inhabited by them, assuming that the waters have been found to have the requisite conditions for grown fish, the first thing to ascertain is the presence of adequate food supply for the young fish. In this case as in the natural waters unless the nature of the food and other requisites of the young of a given species are known, it is better to refrain from planting it until the facts are ascertained. It is more economical and more promising of positive results to investigate first, then plant, than to plant first and then investigate. In other words, plant according to present knowledge; or acquire knowledge, then plant.

PROPAGATION AND DISTRIBUTION OF FISH BY NEW YORK STATE

In 1916 the New York Conservation Commission issued a guide for stocking the inland waters of New York State with food and game fish, entitled "Fish Planting in Public Waters," of which Dr. Bean was the author. Under the heading: "General Principles of Stocking," this pamphlet contains a very valuable discussion concerning what may be termed the technique of fish planting. The principal topics are: "Stream Study and Plans: Essential Preliminaries"; "Planting Points and Food Supply"; "Fry Versus Fingerlings"; "Care During Transportation"; "Importance of Water Temperature"; "Planting"; "Artificial Stream Pools and Side Pools"; "Receiving and Rearing Stations."

Under the heading "Directions for Planting Various Species," the principal fresh-water fishes listed are: "Brook Trout"; "Rainbow Trout"; "Brown Trout"; "Lake Trout"; "Landlocked Salmon"; "Common Whitefish"; "Round Whitefish or Frostfish"; "Lake Erie Herring"; "Ontario or Greenback Herring"; "Tullibee"; "Pike Perch"; "Yellow Perch"; "Small-mouth Black Bass"; "Calico Bass"; "Muskellunge"; "Smelt" or "Ice-fish." Concerning each of these species the discussion is very brief although the statement concerning the character of places in which to plant is specific. This information concerning some of the species is not based upon actual knowledge and the recommendations are the result of inference rather than investigation. While very much lacking in positive information, the instructions are the best possible to be derived from available existing knowledge. The present writer must confess to inability to add much to what Dr. Bean has said, which only goes to show the need of attaining to a degree of knowledge by study of those subjects to render fish planting a rational procedure.

In the following paragraphs concerning fish planting no original instructions are attempted. Brief extracts are made from Dr. Bean's directions concerning each species, and an occasional modification or comment is made.

Since this pamphlet was published Dr. Bean's list of species of fish distributed has had other species added to it and some subtracted from it, according to the Eleventh Annual Report of the Conservation Commission for the year 1921. Also during other years species not mentioned in either list were distributed to some extent. Reference will be made to some of these.

The Trouts and Salmons. The trouts and salmons comprise the most highly esteemed and ardently sought for game fishes in the eastern states, and of the game fishes they have also received the greatest amount of fish cultural attention. A number of other species than those mentioned in this connection have been introduced and distributed in waters of the eastern United States, but with no real success. Only those at present propagated and distributed by the State of New York are discussed in the following pages.

Brook Trout. Bean ('16) states: " The best places for planting brook trout are in the rivulets and spring feeders, tributary to the larger streams, into which the fish will work their way as they grow. Make sure that the brooks are not such as will dry up or become stagnant during the summer. . . . The fry are ready for distribution in March or April and fingerlings from May to July. The latter should not be planted in quite such small streamlets as the fry."

" The streams to be stocked should not rise above 68 degrees in temperature during the summer. Brook trout will not live and thrive in warmer waters. It has been found in various parts of the State that certain streams formerly abounding in brook trout will no longer support this species, and in many cases it is quite evident that this is directly due to the cutting off of the forests and the consequent increase in temperature of the waters through exposure to the sun. The banks of the stream should be grown with trees or tall shrubs in order to provide the necessary shade and coolness. Where the vegetation has been removed, black alder or quick growing willows may be advantageously planted along the banks. It is useless to place trout in waters made impure with sewage, mill, dairy or other refuse, for they are peculiarly sensitive to pollution and will not remain in such waters."

For many years the upper temperature limit of 68 degrees has been observed. But Embody ('21) adduces evidence from experiments tending to show that this standard for the upper safety limit has been set too low, other conditions being wholly favorable. Referring to his experiments with young brook trout and other species in small artificial ponds and " wood races " in 1920 and 1921, Embody emphasizes the point that brook trout will withstand a degree of temperature considerably higher than the usually accepted upper limit. In one instance, " The brook trout passed through a temperature of 83.3 degrees F. without loss, but with evident distress and failure of appetite. They apparently recovered on a drop of nine degrees over night and a maximum of 79.7 degrees the following day. They lived through five succeeding days with the maximal temperatures ranging from 78.8 degrees to 80.7 degrees

F., but began to die at 84.2 degrees (mortality 20 per cent). None died the following day, July 4, at 82.4 degrees; but on July 5 at a temperature of 83.2 degrees F., the mortality was 100 per cent." Concerning the experiments Embody says: "It must be understood that the foregoing rates do not prove that all strains of brook trout will stand a temperature of 80 degrees F., and above. Undoubtedly, there is much variation in this respect just as we find great variation in the rate of growth, in the behavior of trout to current and light, and variation in power of resistance to disease germs.

"Nor may we assume that brook trout will thrive in any pond or stream whose temperatures do not exceed these uppermost limits. Waters vary greatly in oxygen and carbon dioxide content, and these gases may be present in insufficient amounts in one case or too great amounts in the other to permit trout to live even in the low temperatures of the average trout hatchery.

"So far as temperature alone is concerned, however, it is the writer's opinion that we have been a little too conservative and that we shall have to revise to some extent our notions as to the meaning of the terms, warm water and cold water."

In the discussion of Embody's paper at the meeting of the American Fisheries Society, the comments which were more or less adverse to the higher temperature limit, largely pertained to hatchery experiences. But Mr. G. C. Leach, head of the Division of Fish Culture of the Federal Bureau of Fisheries, suggested that the volume of water is one of the determining factors as concerns the temperature-withstanding ability of trout.

Again Embody ('22, pp. 7–8) says that the views which he quotes concerning the temperature safety limits, were made prior to 1880, when the trout brooks possibly were colder than they are today, and continues: "There is a possibility that through natural selection our speckled brook trout is gradually adapting itself to warmer waters. According to present day evidence either this must be true or certain statements of Ainsworth and Green were not based upon complete observation. For upon an examination of the temperature data from certain trout brooks in this county, we find a number of instances where speckled trout apparently thrive and take the hook in waters whose highest temperature ranges from 74 degrees to 79 degrees F. The highest temperature in which speckled trout were found was 81 degrees F. This was in the upper Van Pelt Brook where three specimens were clearly observed apparently not inconvenienced by the high temperature.

"In other parts of this stream, brook trout were observed in temperatures of 76°, 78° and 79° F. In the Dusenbury stream they were seen in temperatures of 79° and 80° F.

"It must be kept in mind that the temperatures referred to were taken on the hottest days of the summer of 1918 when the maximum air temperature in the open ranged from 95° to 100° F. Thus they probably represent the extreme conditions occurring in these streams. In order to find out the fluctuations in water temperatures, a series of readings were taken in a warm, unshaded part of the

Dusenbury stream where brook trout occur, with the following results:

"Fluctuations in water temperature in Dusenbury Brook between 2 p.m., August 6, and 3 p.m., August 7, 1918:

Date	Time	Air Temp.	Water Temp.
August 6	2:00 p.m.	94	80
August 7	7:00 a.m.	79	67
August 7	10:00 a.m.	80	68
August 7	12:30 p.m.	85	70.5
August 7	1:30 p.m.	91	76.5
August 7	3:00 p.m.	94	80

"The extremes of water temperatures as read are 67° and 80°, a daily range of 13°. It is doubtful that the water temperature went lower because the minimum air temperature recorded by the local weather bureau was only 79°. From these readings it is evident that the high-water temperatures are *not of long duration* [italics the present writer's], probably not longer than five hours. It is, therefore, clear that some speckled trout experience no ill effect from temperatures of 79° and 80° when only of short duration. While it may be true that a temperature above 70° F. would be unsafe in a crowded hatchery pond, the writer feels that for wild, rapid, unpolluted streams the unsafe temperature is higher; how much so he is not prepared to say. The temperatures of 79° and 81° as stated above, however, are very significant even though they may not obtain in many trout streams. Notwithstanding these extreme cases the writer prefers to err on the safe side and therefore recommends as a basis for future stocking with brook trout that 75° F. be taken as the dividing point between 'cold' and 'warm' waters."

Embody also refers to "other factors" than temperature to be considered, saying that trout may thrive in one brook where the temperature is 80° but not in another. This point has been discussed in preceding pages, but perhaps it may be well to suggest that the same may possibly obtain with trout and 75° F.

The present writer is inclined to regard it unwise to accept the old views and conclusions as irrefutable unless they have been established as scientific facts. He also recognizes that the term, "established scientific fact," like "warm" and "cold" may be a relative one. But any claim that the results of a very limited amount of observation in a restricted field upsets all conclusions based upon years of experience and observation in a wide field, should be carefully considered with all the evidence in hand.

Embody's investigations are valuable and his observations in those directions are commendable and should be continued. But, because his observations appear to be at variance with the older ideas concerning temperature, especially when he admits that other factors are doubtless concerned, to attempt to explain the phenomena by attributing them to "adaptation through natural selection," to the present writer would appear to be dangerously near "deep water." At any rate a discussion of that subject in this connection would be out of place. However, it may be that the present writer is so obtuse as to take Embody's remark literally and as seriously intended when it may have been merely to emphasize the contrast in the results of his temperature observations with the long standing belief that 68° F. was the dead line in the upward temperature range for brook trout.

Be that as it may, it would appear to the writer that in planting trout the slogan, "safety first," should be regarded, until it is established that everywhere and under all conditions 75° F. is well within the natural temperature range. If it is proved to be so, it will not signify that a new adaptation is taking place but that it is one condition which is comprised in the consummation of thousands of years of adaptations to changing environment and other conditions through a complex of natural forces and "factors" which has been indefinitely referred to as "natural selection."

In the study of conditions of the streams in Allegany State Park in August, 1922, no trout were observed below the wooded region. In Quaker Run the temperature varied from 52 to 67 degrees F., being coldest in the upper waters and progressively rising downstream. The temperatures were taken on different dates from August 1 to August 28, at different times of day from about 10 a.m. to about 4:30 p.m.

From the upper waters to a certain point in the stream the temperature averaged 53.7 degrees and at no time exceeded 55 degrees, and that figure was observed near the place mentioned, simply indicating a transition into the warmer waters below. Below the said point the temperatures ranged from 58 to 67 degrees, averaging about 61.7 degrees, from August 2 to August 28, between 10 a.m. to 3.15 p.m.. the higher readings being found lower down and latest in the season. It is interesting to find that in the neighborhood of this point a notable limitation of the fish distribution occurs. Certain species occurring below do not occur above. Others which continue to some distance above these are not found still further up. Others continue still higher, then cease. And, finally, only one form is found associated with the brook trout throughout.

At the precise point referred to is a large pool in which two good-sized brown trout were observed (figures 38, 39). One fingerling brown trout was found a short distance above. While brook trout occurred throughout the wooded section of the stream, they were most abundant above the point mentioned.

A small tributary stream joining Quaker Run some considerable distance above this point showed a temperature of 55 degrees on August 7. It contained a good many small trout for the extent of the stream. On the same day a mere rivulet some distance below this tributary showed a temperature of 62 degrees. It contained some young trout. Below this another rivulet of about the same size showed, on August 11, a temperature of 56 degrees.

One of the most considerable tributaries of Quaker Run joined the stream near the previously mentioned dividing point. The temperature taken on August 11, 12 and 14, in different sections of the brook from 9:30 a.m. to 3:00 p.m. ranged from 54 to 61

Fig. 38. A deep pool in Quaker Run, Allegany State Park. Both brown and brook trout occur here.

Fig. 39. Quaker Run where it enters the pool shown in figure 38. An excellent spawning place for trout.

Fig. 40. A large pool on Quaker Run, at beginning of open stream, probably below summer trout limit.

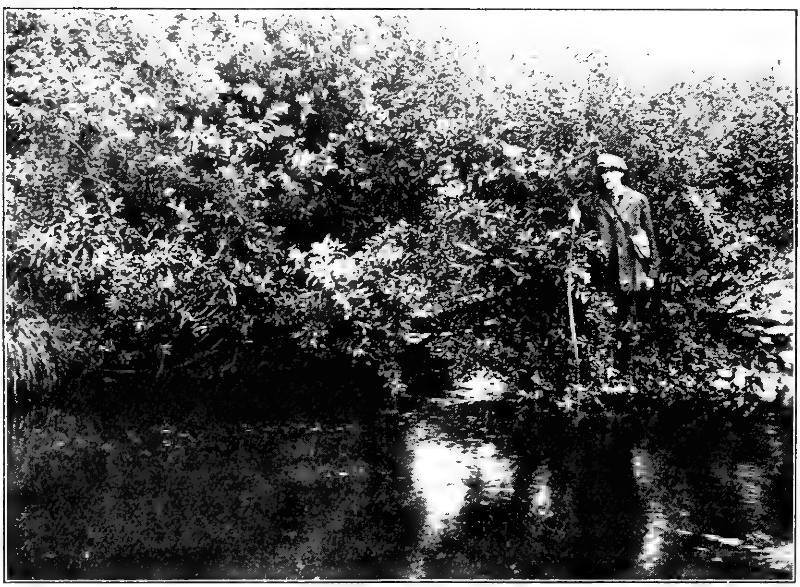

Fig. 41. Quaker Run near where English Run enters. A good trout brook above this point.

and averaged 56.6 degrees. The weather conditions were clear and warm on the first two days and on the last day clear and very hot. Trout were common in this brook.

Another considerable tributary joins Quaker Run just below the wooded section of the stream, the lower limit of the season's observations (figures 40, 41). Trout were common in this brook, particularly well up the stream. The temperature ranged from 64 to 67 and averaged 65.5 plus, on August 16 and 18, from 10:30 a.m. to 4:30 p.m. The weather conditions were clear and hot.

In connection with a large, rather open pool in the woods, which contained trout, the following temperature observations were made: Air in the shade 81°, in sun 91°; running water in shade immediately above the pool, 64.5°; in the pool immediately below, 65.5°; running water immediately below the pool in shade, 65.5°.

August 17 was a clear, very hot day. On that date a section of brook tributary to Red House Creek was examined. In the upper section of the brook, which was in the rather heavily wooded hills, the temperature of the air in the shade was almost uniformly 75 degrees. The temperature of the brook was uniformly 59 degrees excepting near an inflowing spring where it was 58 degrees. Emerging from the woods into an open country, a small shallow pool was observed which contained one trout 7 or 8 inches in length. The temperature of the air in the shade here was 80 degrees and that of the water 74 degrees. Seventy yards further along in the open country was a pool under a shelving ledge where a number of fair sized trout were glimpsed as they disappeared under the shelf. The temperature of the air here was still 80 degrees in the shade, and that of the water was 75 degrees. Not far below the brook joined Red House Creek, where the air registered 92 degrees and the water in an open pool 85 degrees.

In connection with the 75 degrees set by Embody as a dividing point this is interesting, as it shows a rather sudden transition from "cold" to "warm" water, and that the intermediate section was occupied by trout only at its upper end, although apparently in 75 degrees of water temperature. It was impossible, however, to determine the temperature under the shelf. The open brook below contained multitudes of black-nosed dace, very few of which were found above the open tract. Red House Creek was "alive" with cyprinids of several species, suckers, and small blackbass.

If the limited temperature observations of the Allegany Park trout streams could be regarded as significant of anything concerning brook trout they would indicate that the optimum conditions are in waters not warmer than 60 degrees, and that 75 degrees represents the limit of even temporary endurance. However, the present writer makes no claim that they are sufficient for such a deduction. But given a stream the temperature of which does not exceed 60 degrees in the hot season, other things being favorable, no one need hesitate to plant brook trout in them. If the higher degrees are observed, other conditions such as possible hotter and dryer seasons must be considered also.

Lake Trout. Bean referred to the lake trout as one of the largest and most beautiful of native species of the salmon family, which thrives in cold, deep lakes, and is an omnivorous feeder, subsisting chiefly upon ciscoes or lake herrings and other small fish; but he said nothing concerning the food of young lake trout.

It was stated that the fry were ready for distribution by the Commission in March or April, the fingerlings from May to July, and that they should be planted on rocky shoals or reefs in lakes, very near to deep water.

In the report upon the work at Lake George, Dr. Emmeline Moore, one of the participants, whose special subject was "the primary sources of food of certain food and game, and bait fishes," states (Moore, '22) that the natural food of the very young lake trout still remains a mystery. Nevertheless recommendations are made by other investigators and contributors concerning the planting of young lake trout. Dr. Needham says that it must be remembered that their first food will be water fleas and other minute plankton; that these are taken by mechanically straining the lake water through the gill rakers, and that a large quantity of water must be strained to get the hundred or so of the water fleas required for a single meal.

This appears to be a statement based upon analogy and not upon direct observation. Very likely, if lake trout fry were planted in the places recommended, they would be compelled to feed upon the small organisms mentioned or nothing.

The recommendations to plant the young lake trout in water deeper than 40 feet was not based upon any known food requirements of the young fish, but upon freedom from enemies at that depth. But in the same report Mr. Titcomb well says that it is hardly natural to transfer fingerling trout from the shallow water of the rearing troughs, not over six inches in depth, to water fifty feet in depth, and that it is a matter of conjecture as to whether they are prepared for so sudden a change in water pressure as they will encounter at a depth of fifty feet, where they will actually go after diving out of sight.

It may be added that what they will feed upon if they remain at those depths is also a matter of conjecture.

Nevertheless Titcomb accedes to the recommendation, but adds that if by strictly adhering to the revised methods of fish planting the trout of Lake George do not come back as expected, the only alternative will be to keep them in breeding ponds until they are a year older before planting; and that in the meantime, further efforts should be made to learn something about the life history of the lake trout under natural conditions, from the time it hatches on the spawning beds until it is a year or two old.

Besides the uncertainty of the young fish being able to withstand the unusual pressure at a depth of 50 feet, there may be some doubt whether a fingerling lake trout is capable of straining the minute organisms mentioned as its prospective food in deep water, in sufficient quantity to afford it a meal.

The whitefish or "Lake George Smelt" is a plankton feeder. Its gill rakers number about 55 on the first arch on each side, and are close set, which with the corresponding arrangement on the other arches provide a very fine strainer. The lake trout has less than half that number, and they are not very close set.

Mr. Titcomb further said: "Unfortunately the biological survey did not result in the capture of any immature trout, and the life history of this species up to one or probably two years of age, their feeding habits and their chosen environment remain incompletely known. There is no definite knowledge of the early life history of this species in connection with other lakes. The smallest specimen taken by the angler is said to be eight inches long, or a two-year-old fish. Since they will take the angler's lure, it may be assumed that the 8-inch fish feed upon young whitefish. From fish cultural experience, it is probable that they begin eating small whitefish at a much earlier state."

This last statement is also conjecture. The present writer would suggest that it would be more economical to immediately set about learning the life history of the lake trout, and in the meantime carry out the "alternative," if upon due consideration it seems advisable, rather than plant fingerlings of which the habits are unknown, in water of the depth mentioned.

As a small contribution to the life history of the lake trout, it may be mentioned here, that nearly twenty years ago the present writer found "fingerling" lake trout in a rivulet and a small brook tributary to First Connecticut Lake in Northern New Hampshire (Kendall and Goldsborough, '08). The following are the data:

July 16. In a spring rivulet tributary of the main inlet not far above its mouth, several were caught, two of which, 2.37 and 2.08 inches long, respectively, were saved.

July 18. In the same rivulet another specimen 2.08 inches long was taken.

August 10. In Alder Brook, directly tributary to the lake a mile and a half or more from the first mentioned rivulet four were caught, measuring 2.08, 2.06, 2, and 1.87 inches long, respectively.

The stomachs of the first mentioned specimens contained "black fly" larvae, insect fragments, and an insect egg. The contents of the stomachs of the lot taken on August 10 were black fly larvae, insects' heads and wings, and "mosquitoes."

As concerns the insect larvae and insects, after such a lapse of years, the present writer cannot be sure that the larvae and mosquitoes were correctly identified. However, it is quite positive that both were dipterous insect forms, and it is not especially essential to know the species. It is sufficient to know that these fingerlings were in little brooks and were feeding upon dipterous insects, both larvae and adults.

Whether these fingerlings were some of the recently planted fish or naturally hatched fish is not known. Whichever they were their presence in these little brooks is significant. It is not known where or just when the 25,000 young lake trout were planted, or whether fry or fingerlings, but it is fairly certain that they were not put into these little streams. The point is that fingerling lake trout were in a rivulet and small brook and were feeding upon insect larvae and insects. In an effort to ascertain the habits of young lake trout in Lake George or elsewhere it may be well to search the small brooks flowing into the lake. It is well known that salmon and brook trout fingerlings, hatched in a larger stream, make their way into smaller tributary brooks and rivulets where they remain until they have attained a considerable size.

A good example of a "deep water" fish having like habits is that of the Burbot (*Lota maculosa*). The present writer found young of this species, 1.9 to 2.45 inches long in spring pools of a small spring brook in a hay meadow on Indian Stream in the Connecticut Lakes region. The brook at this time was not connected with Indian Stream (a tributary of the Connecticut River below First Connecticut Lake), but doubtless had been during higher stages of water. In the same region young of the same species, from 2.75 to 6 inches long were taken in East Inlet of Second Connecticut Lake. The stomachs and intestines of all these young fish contained a variety of food consisting of fragments of insects, larval insects ("black fly"), Entomostraca and mites. Young burbot have been found in brooks of various other localities.

While the burbot affords no direct evidence concerning the lake trout, the above facts are mentioned to indicate that although the lake trout is a "deep water" fish which spawns in the lake, the young are not necessarily deep water inhabitants.

Rainbow Trout. Bean says that this is a native of the mountain streams of the Pacific coast, where it occasionally descends to the lower stretches of the rivers and even passes out to sea. He states that its food as well as its habitat is similar to that of the brook trout and that both fishes will live in harmony in the same waters, but that the rainbow seems to show a tendency to work downstream, passing over dams and falls that it cannot ascend again, thus abandoning the headwaters. He goes on to say that it has been introduced with great success into lakes that are landlocked, so that it cannot escape, but that such lakes should have small tributary streams up which the rainbow can run to spawn.

Embody ('22) indicates that rainbow trout will live in waters where the temperature ranges upwards of 85 degrees and suggests that there is good evidence for believing that it will do well in waters the oxygen content of which is a little lower and where pollution is a little greater than is the case with brook trout. He says: "Resistance to high temperature and to certain conditions fatal to brook trout makes it possible for the sportsman to stock many streams with brown and rainbow trout which would otherwise contain only minnows and suckers."

Again referring to the rainbow trout, Embody says: "There is another factor to be considered in the case of that fish and that is the migratory instinct. The practice of introducing rainbows in many small streams is very likely to result in failure because the stock generally put out in the East is of the migratory variety. These rainbows seem to remain in the stream until they are a year old and in some cases two years old, after which they go down stream to the nearest large body of water whether a lake or a large cold river. The majority of rainbows taken in a small stream outside of the spawning season are from 4 to 8 inches long, although in exceptional cases a few up to one foot long have been captured. But the larger, heavier fish are rarely if ever taken in brooks except during or just after the spawning season in April and May.

"Now if rainbows are planted in small streams which have no immediate connection with a lake or large cold river, they are sure to leave the stream permanently before they are large enough to furnish good sport, but if a large cold lake is available the larger fish will spend most of the year in the lake, returning to the brooks in spring to spawn. Thus it is hardly worth while to plant rainbows in streams which do not flow directly into some lake or cold river or in those where the ascent of trout in spring is blocked by impassable falls."

There appears to be some inconsistency in what Embody says concerning requisite conditions for rainbow trout. The statement that they will live in waters where the temperature ranges upwards of 85 degrees and possibly in lower oxygen content than the brook trout is not exactly in accord with the statement that it is hardly worth while to plant rainbows in streams which do not flow directly into some lake or cold river. The latter statement, however, agrees with Bean's remark that the rainbow seems to show a tendency to work downstream. The belief in this tendency is traditional and almost proverbial. For many years the idea that the rainbow would not only stand but requires warmer water than the brook trout has been prevalent, but some fish culturists have taken exception to this generally accepted rule. As long ago as 1886, the first noted success in acclimatization of rainbow trout was announced as having been accomplished in streams of the Ozark Mountains region. An inspection of Spring River, a tributary of the Arkansas, showed that at least three generations of trout were present as the result of a plant of fry in 1880. The largest fish observed weighed between four and five pounds. The second in size measured 15 to 17 inches, while the sources of the stream swarmed with thousands of young from 4 to 5 inches long. Of the streams it was stated that they were "clear and cold, the temperature of the water not rising above 58 degrees in the heat of summer." (Bull. U. S. Fish Commission, Vol. 6, 1886, pp. 447–448.)

A former Commissioner of Pennsylvania (Meehan, '95) wrote: "The rainbow trout early attracted the attention of the government authorities engaged in fish culture, and they felt the desirability of transplanting the species into eastern waters. While this was a laudable sentiment they fell into an error which, being spread broadcast, for several years and even yet to some extent caused and is causing much useless labor in stream planting. Finding the rainbow trout were abundant and indigenous in streams of a very warm climate, the government authorities before noted, without giving the matter close attention, arrived at the conclusion that this fish would thrive in waters of a higher temperature than the eastern brook trout, or charr, and so publicly expressed themselves. The result was that as soon as the first lot of fry were ready for distribution, there was a widespread and great demand for them. Many of these fish were placed in streams the water of which was as high as 70 degrees, and in which there was not even the compensation of aeration by extreme rapidity of flow. To the surprise of those who stocked streams of this character and even many waters in which speckled trout lived, there was not a vestige of the fish. Of the hundreds of streams in this state stocked with rainbow trout fry supplied by the government and by the Pennsylvania Commissioners scarcely any planted in the early years of the experiment yielded any returns. At length the secret was discovered.

" In taking the climate of California as a basis for the expression of belief that the rainbow trout would thrive in water of a higher temperature than the eastern brook trout, the authorities made a grave error. While the climate was much warmer, the waters in which the rainbow trout had their original home was of the coldest, purest character, having their sources in the perpetual ice and snow of the mountains. As a matter of fact, instead of thriving in warmer water, the rainbow trout actually demanded colder water for their well-being than the eastern trout. Since this discovery the planting of rainbow trout has met with greater success but the work is still far from being satisfactory."

As previously noted, Bean says that its food as well as its habitat is similar to that of the brook trout and that both fishes will live in harmony in the same waters. In another publication (Bean, '97) he says of the rainbow trout: " Contrary to what has been stated heretofore, they will not endure high temperature as well as brook trout."

On the other hand, in a discussion of a paper read at a meeting of the American Fisheries Society (Seagle, '02), Mr. Titcomb, among other things said: " These rainbows have been introduced in New England and New York State, and in most cases have disappeared after a short time. I have in mind one stream where rainbow trout were introduced by accident. A gentleman had a private pond and reared some rainbow trout and they got into this stream which was a natural trout stream, but the lower end of it warmed up too much in summer for speckled trout. These rainbows held their own in that stream for a number of years, but all the best fishing was at the lower end in warm water, but they did breed there naturally for a time — in fact at one time there were three rainbow trout to one speckled trout — and yet today you perhaps catch in that stream in the course of a season a dozen rainbow trout, but the speckled trout still holds its own. There are lots of places in Vermont where we have introduced rainbow trout and they have entirely disappeared — just the reverse of Mr. Dean's experience in Missouri."

In a discussion of a paper by the present writer read at a meeting of the American Fisheries Society (Kendall, '20), Mr. Titcomb said: "Something like thirty years ago I was talking with United States Commissioner McDonald, and I asked him what results he had obtained with rainbow trout in the East. I remember he stated that they had sent great numbers of them into the waters of New York State, and that they had all disappeared. I have not had much experience personally with New York waters, but it is particularly interesting to me to study the results of planting rainbow or steelhead trout. We do not know absolutely what waters are suitable for rainbow trout. It is a curious thing, but we have streams in New York and a few in Vermont where planting of rainbow trout has been followed with very good results, and where they have reproduced and maintained themselves afterwards. But in the majority of these streams in New York State where the rainbows have been planted, the fish have absolutely disappeared; and yet there are streams which we annually plant with fish and which afford good fishing for the rainbow trout, so-called. It is corroborated by anglers that these are good rainbow trout streams. Now we choose for the rainbow, as we do for the brown trout, the lower waters of the streams where the tendency is for the water to become considerably warmer and is not congenial for the native brook trout. We do not consider the rainbow so destructive to the brook trout as the brown trout. The rainbow trout, if planted in the headwaters, naturally works down into the larger, deeper pools of the lower part of the stream, where the temperature is higher."

No adequate explanation for the vagaries, idiosyncrasies or uncertainties of the rainbow trout as shown by the foregoing quotations, and many other accounts of experiences, has ever been offered.

The paper to which Mr. Titcomb's discussion just quoted pertained was an attempt to indicate the present situation as concerns the rainbow trout of eastern fish culture. It stated that from about 1880 to about 1895 the only rainbow trout propagated and distributed in the East were raised from eggs of trout from the McCloud River, which is one of the headwater tributaries of the Sacramento River. For a number of years the propagation of the rainbow met with varying success according to the conditions obtaining where its propagation was carried on. It was found that they did better at some hatcheries than at others. But finally difficulties and puzzling conditions arose for which the remedy was thought to be the adding of "wild" rainbow trout to the "domesticated" brood stock.

At first these wild trout eggs came from California, but as the records show, not from the McCloud River but from the Klamath River basin where the McCloud trout did not occur. Later, wild rainbow eggs were taken in Nevada and Colorado. In both of these places the rainbow trout were originally introduced, and consisted partly of McCloud trout and partly of Klamath trout. Still later the United States Bureau of Fisheries has been securing its wild trout eggs from fish of the Madison River, Montana. These were also introduced. Steelhead trout were also introduced into the same stream. The propagation of steelhead trout was undertaken much later than that of the rainbow, and their eggs have always been taken from undoubted steelhead trout from Oregon and Washington. Unfortunately a long discussion of names of the rainbow and steelhead confused the minds of fish culturists and many were misled to believe that the rainbow trout and steelhead were one and the same species, and they accordingly mixed them and propagated and distributed them together as rainbow trout.

However, prior to the United States Fish Commission trout operations in the McCloud River, the State of New York undertook the introduction of western trout into New York waters. Bean ('09a, p. 250) says:

"Importations of California brook trout were received with the intention of placing them in New York waters. On March 31, 1875, 1800 eggs were received, but a number of them were lost in transportation, and on January 7, 1876, there were 260 alive, looking fine and healthy, and about three inches long.

"At Caledonia, according to the Tenth Report, a pond contained trout of this kind which were then about two and one-half years old. They were considerably larger than brook trout of the same age. They are a hardier fish and do well in New York waters. No eggs have yet been given by these fish.

"The Commissioners recognized two kinds of trout in California, the mountain trout and the McCloud River trout.

"In the spring of 1875 the Commissioners received 500 eggs of the mountain trout from Mr. Newell, of San Francisco. Of these 300 hatched: they lived and grew until they were three years old and commenced to spawn, which was in the spring of 1878. They then weighed a pound apiece and only twenty-five of them had died. The remaining 275 gave 64,000 eggs which when hatched were distributed throughout the State, with the exception of 17,000 retained at the hatchery for breeders. In the spring of 1879 there were of the old fish 260 still alive, and they being then older and larger than the year previous produced 94,000 young. These were all distributed but 34,000 of which we lost scarcely any, so that in January, 1880, we have about 250 five years old, 17,000 two years old, and 34,000 one year old. . . . ."

"Of the McCloud River trout eggs 5,000 were obtained in 1879 by an exchange for an equal number of our brook trout eggs. They hatched in the spring of that year, and at the time of the Eleventh Report they had by actual count made, while moving them from one pond to another, 4,742, showing a loss of only five per cent in both hatching and raising."

From the foregoing it is seen that even from the beginning the New York Commissioners recognized two kinds of trout, but whether they recognized differences of structure or appearance or just a difference of names is not known. As a matter of fact the "mountain trout" and McCloud River trout were distinct species.

Or it should be said that a McCloud trout which entered into the United States fish cultural operations was a different species from the mountain trout of coastwise streams. More than one kind of trout has been stated to have occurred in the McCloud River; Jordan described and named two species. There is evidence that one of the two was possibly the same as the fish now known as steelhead. So even in the stock derived from the McCloud River there may have been a mixture from the start.

Whatever the composition of brood stocks may have been it is known that in many instances the so-called rainbow trout have been mixed and interbred with steelhead trout. Also that some steelheads have been distributed as rainbow trout. So it is quite clear that there are positively two, and more than likely, three species comprised in the propagation and distribution of rainbow trout in the East. It is more than merely possible that the observed differences in habits of the rainbows and the differences in results in stocking waters with them may be attributable to this fact.

In stocking waters with rainbow trout, then, it is highly essential to know what form is being planted, but even a trained ichthyologist might be "stumped" in trying to identify the young. In localities where successful acclimatization has been effected the matter is simplified if an adequate egg supply is obtainable from the "rainbows" of the locality. As long as the fish is satisfactory to the angler in every way, it won't matter much to him whether it is one species or another and he can continue to call it a rainbow with no harm done. In propagating and distributing that form, the essential thing is to determine fully the habits of the fish, and the exact conditions of the water in which it has proved a success and compare the data with the obtaining conditions in the body of water which it is desired to stock.

As concerns hatchery brood stocks it would appear desirable to ascertain their actual composition, if possible, and select the form, if there are more than one represented, which appears to be the successful one in the waters already satisfactorily stocked.

Where a brood stock is an unadulterated one like that mentioned by Nevin ('20), the problem would appear simpler. He said: "As to rainbow trout, I think we keep a larger stock of breeders and take more eggs than any of the middle or eastern states. We do not have the trouble in raising them that we do with the brook trout in the same waters where we hatch and distribute millions of fry. These fish have been bred from the same stock for the past forty years, and the eggs and fry from our stock of breeders last season were as strong and vigorous as any we had ever taken."

From the foregoing it becomes quite evident that definite instructions concerning stocking with rainbow trout cannot at this time be prescribed. However, Bean ('16) says that since the rainbow spawns somewhat later than the brook trout, the fry are not ready for shipment until May or June, and the fingerlings from July to September.

Brown Trout. Bean stated ('16) that the brown trout is a native of Europe, and that it has become acclimatized in many parts of the United States. He said that it is very hardy and ranks as one of the finest game fishes, and that it lives in clear, cold, rapid streams, its food and habits being similar to the brook and rainbow trouts'. He added, however, that since this fish grows to a much larger size and preys upon the others, it should never be introduced into waters already supplied with native trout. He further stated that it withstands a higher summer temperature than the brook trout, and has replaced that species in certain waters where the surrounding forests have been largely cleared away.

Embody indicates that the brown trout will live in water up to 83 degrees and possibly in "a little lower oxygen content" and "where pollution is a little greater" than in the case of brook trout.

W. C. Adams ('20) says that "in 1917, after four extraordinarily hot days, there were found at the dam at Littleville [Massachusetts], where the water was 84 degrees, 37 dead brown trout weighing from one to five pounds eight ounces, the largest 27½ inches in length. This occurred at a time when the river was unusually low. In normal times the fish would have saved themselves by dropping down to cooler water."

This would suggest that 83 degrees of heat is somewhat too near the danger line to be accepted as a standard of upper temperature limit for the safety of brown trout, and especially if there is lower oxygen content or pollution.

Embody ('22) says: "It is believed that of the three trout the brown trout is the most predacious and most destructive of other fish and it is often stated if a stream is stocked with all three species the browns will eventually exterminate the others. There are many streams where brook trout have disappeared or become greatly reduced in numbers a few years after the introduction of brown trout, but it has in no case been proved that the brown trout has caused the trouble. In fact there are streams in Tompkins County where the brook trout and brown trout occur apparently in equal numbers and have lived so for a number of years."

"Often the upper part of a stream," he says, "is well suited to brook trout while in the lower part browns only will survive. In such cases an impassable dam or falls conveniently located will make it possible to stock the lower part with browns without injuring the brook trout fishing above."

Concerning this fish, Nevin ('20) says: "We intend to increase our capacity and keep a much larger stock of brown trout in the future than we have in the past, as the fry planted in our streams have done exceptionally well. I do not find from observation that the brown trout are any more destructive in the way of cannibalism, of which they are accused, than any other variety of game fish."

The present writer is emphatically opposed to the brown trout in any waters where the brook trout exists or can be made to exist. There are waters which have become unsuitable for brook trout, in which brown trout have become established and afford satisfactory fishing. His advice is, however, to refrain from planting them in any stream or pond suitable for brook trout, or in waters from which they can gain access to brook trout waters, although it is doubtful if brown trout would thrive in numbers in the colder trout streams. But some might live, and those which do survive become competitors for the food of the brook trout, even if they do not harm the latter directly. Furthermore, there are certain waters which are intermediate between the best environment of brook trout and the best for brown trout. In such places brook trout can be satisfactorily maintained but if brown trout are added the brook trout may succumb. This advice is given with reservations, however, and is subject to revision in the light of further knowledge. The present writer may be sentimentally influenced but he believes that there is no better trout than the brook trout and that we should maintain it whenever possible.

Bean said that the fry of the brown trout are shipped in March or April, the fingerlings from May to July, and are planted as in the case of the brook trout.

Steelhead Trout. The steelhead was not included in Bean's (1916) list of fish propagated and distributed, but the list in the Eleventh Annual Report of the State of New York Conservation Commission for the year 1921 included it. A table is also given showing the numbers of fish distributed each year from January 1, 1917 to December 31, 1921.

Of steelhead trout fingerlings there were 284,660 in 1917; 74,100 in 1918; 142,900 in 1919; 466 in 1920; and 118,000 in 1921.

Although steelhead trout have been planted as rainbow trout, wherever they have been placed under the name of steelhead, one is fairly sure of the species. At least it is known that the eggs have been derived from Washington and Oregon fish which were ascending the streams from the sea and that the question is not as complicated as is that of the rainbow trout. There have been successful acclimatizations of steelhead trout in eastern waters, the most notable of which is its establishment in Lake Superior. It is known to have become established in some small lakes also, but in them appears seldom to attain a considerable size. However, the steelhead is not regarded as a suitable fish for streams in which a permanent resident is desired and it is advised to plant them in the large lakes only, and then only provided the waters are not already stocked with native salmonids. As a game or food fish, it should be remembered that it spawns in the spring and is likely to be in poor condition during the usual trout fishing season, and that it is in its best condition only in late summer and fall.

As the steelhead spawns in running water the same cautions and rules apply to planting the fish as in the case of others of like habits.

Landlocked Salmon. All that Bean said of the landlocked salmon was that only a small number of eggs of this species were obtainable, through the United States Bureau of Fisheries, and all the fry were planted by the Commission in Lake George.

The general situation as concerns this species is discussed elsewhere in this paper (pp. 273-275). In the Lake George report, Titcomb says of this fish: " In response to a public demand, landlocked salmon have been planted annually in the lake: 15,000 or 20,000 and sometimes more have been put in the lake or in the tributary streams for a long period of years. Reports indicate that the results have been unsatisfactory, an average of about ten mature salmon being caught from the lake each year. The salmon are stream spawners, and the fish have usually been planted in the trout streams tributary to the lake. It is their habit to remain in the streams until they are from a year to a year and a half old, or until they are eight or nine inches in length. During this period they have a line of red spots along the lateral line, and many anglers make the mistake of catching them for trout. Some of the streams are fished very hard, and these immature salmon respond to the lure of the fly fisherman more readily than do the native trout. It is probable that a large proportion of the fish which reach six inches in length are killed by the angler before they have an opportunity to reach the lake."

He refers to one stream where to reach the lake they have to run the gauntlet for the last mile in a comparatively small channel of still water inhabited by " northern pike " and other spring-raised fishes to reach the portions of the lake which are congenial to them. It is stated that this stream is the most important tributary of the lake for landlocked salmon and that it is reported that an occasional mature salmon has been seen there in the fall of the year, evidently having returned for the spawning function but never in sufficient numbers to indicate that they have become established in the lake.

Titcomb was of the opinion that improvements would follow if the young salmon were planted in one or two streams and these streams kept closed to all fishing, but regarded it as a still better procedure to rear them up to a length of eight or ten inches, " the size when they naturally leave the streams," and then to plant them in the lake.

Keil ('21) stated that if really good results are to be expected from planting landlocked salmon in deep lakes containing no permanent tributary streams, the fish must be held, regardless of size, until they have passed the parr stage and begin to take on the silvery coloration of the smolt. In a discussion of Keil's paper Mr. Titcomb, among other things said:

" Some of you know the difficulties of getting landlocked salmon introduced into your waters. The State of New York has been planting salmon in its lakes for the past 25 or 30 years, and today there is not a public lake in the state where we have any salmon fishing. Every year from 20,000 to 30,000 are hatched and during the last four years we have put out as high as 100,000 salmon, chiefly in Lake George, with an annual yield of perhaps 10 adult salmon a year to the anglers. The fish were formerly planted in the lake, and later in the tributary streams, where I believe they should be planted. A good many were caught from the tributary streams when they still had the red spots which they carry until eight or nine inches long. After the investigation we decided it was useless to attempt to stock a lake like that, unless we could carry the fish through the smolt stage. The State today has one lake entirely under its control, posted and screened, where they have been planted for three years to determine the possibility of developing a source of supply for eggs."

Basing the view upon the known habits and habitat conditions of fry and fingerlings it would appear to be a reasonable assumption that the best places to plant such young salmon would be in streams which afford the requisite conditions for the young fish until they attain the size or age when they descend to the lake. This point has been discussed in preceding pages.

What determines the time of migration or descent to a lake has not been ascertained, and it is a subject which should be investigated.

If, however, it is necessary to plant young fish directly in a lake whether there are suitable tributaries for breeding fish or not, they should be reared to the stage suggested by both Titcomb and Keil. It appears very probable that the widespread lack of success with landlocked salmon stocking and the decline of the fish in their original lakes may be due in part if not largely to planting fish, when too young, directly into the lake or into other unsuitable waters. However, as previously remarked, a self-sustaining stock cannot be expected if not aided by natural breeding.

Fishes Other than Salmonids. Many other species than trouts and salmons are propagated by the Federal government and certain states. Only a comparatively few of them are generally regarded as game fish, although some may be game fish in one locality and not so considered in another. Some species are propagated mainly in the interest of the commercial fisheries, although one or more of these may be regarded as game fish, at least locally.

As previously noted the fish cultural attention of the New York State Conservation Commission is principally directed to the trouts, but it also propagates or rears other fish for either game fishing or commercial fishing, or in some cases, for both purposes.

The limits of this bulletin prohibit a detailed discussion of all species of "artificially propagated" fishes, even if there was available information concerning them. Therefore, only those at present distributed by the Conservation Commission are included in the following discussions, and most of these not because any additional light can be thrown on them but to call attention to the deplorable dearth of knowledge concerning them, and to indicate the need of investigations which they have never received and which they must receive before success will follow the fish cultural efforts.

The Blackbasses and Crappies. Probably next to the trouts the blackbasses are the most ardently pursued game fish. There is probably more detailed knowledge concerning these two species than most other game fish, not excepting the brook trout. For that reason their culture has in late years been attended with general success. Mistakes have been made in transplanting, but they may be avoided in the future, if the lesson from the mistakes is heeded.

The blackbasses are classified as members of the sunfish family which also includes not only the well-known sunfishes but various other species such as the rockbass, crappie and others.

In New York besides the blackbass the only other member of the family now to any extent propagated appears to be the "calico bass" or black crappie.

1. Small-mouth Blackbass. According to Bean the food of the young consists of crustaceans, insects, and insect larvae. Emmeline Moore (*'22*) made a very complete record of the food of this species. She says: "Young bass begin their carnivorous existence at once as they rise from the nest. Before the yolk sac is fully absorbed they are actively feeding upon the most minute midge larvae, waterfleas, or other small crustacea. Their taste and capacity for larger prey is rapidly acquired, but they continue to select much of their food for the first few weeks from the same or similar groups of organisms, even under varying conditions of environment."

From her records, she says it appears that the most important single items in the food of the young small-mouth bass are waterfleas.

It is known that fry of this species linger for some time in the vicinity of the place where they are hatched; so the places suitable for spawning nests being known and the presence of food being ascertained, the fry should be planted in such places. But Bean says that the Commission does not distribute bass fry, and that fingerlings are available for distribution in September and may be planted in the shallow parts of the water to be stocked.

In Lake George, Titcomb (*'22*) states that during the month of August fingerling bass were in evidence about the islands and landings on the lake shore almost everywhere. From what is known of them elsewhere it may be assumed that in most suitable waters they will be found in like situations in September, and that fingerlings may be planted accordingly. In any event there appears never to have been any difficulty in stocking with blackbass.

2. Large-mouth Blackbass. Bean did not include this species in the list of those planted by the New York State Conservation Commission. Except in large bodies of water with a diversity of conditions which would afford adequate habitats for both species of blackbass, it would not appear advisable to plant both in the same water.

Forbes ('80), from an examination of a few specimens, indicates that this species in infancy subsists largely upon Entomostraca. While some Entomostraca were eaten by blackbass an inch to two inches in length nearly half of the food consisted of insect larvae and insects; also some fish were taken. When from two to three inches long the food consisted entirely of insect larvae and insects. The food of adults was largely composed of several kinds of fishes and some crayfish, 86 per cent of the food being fishes.

Pearse ('15) shows that young blackbass from about two up to a little less than two and a half inches fed upon small larvae, insects, amphipods and Entomostraca; and that from twenty-seven specimens from about two inches up to about four inches, averaging a little over three inches, the diet was composed of 14.2 per cent fish, 31.2 per cent insect larvae, 38.6 per cent insects, 3.8 per cent amphipods, 2.5 per cent Entomostraca, and 1.6 per cent plant fibre. Moore ('20) says that Chironomid larvae are among the most important single items in the dietary of the young of this species.

3. Black Crappie. Bean says: "This small bass occurs in streams as well as in lakes and ponds, and is a very good game fish. Its average weight is about a pound. Its food consists of worms, small crustaceans, and fishes."

"Fingerlings are available at the same time, and may be planted in the same way, as blackbass."

Concerning this species Pearse ('19) gives the following summary of his observations made in Lakes of Wisconsin in 1916.

"1. This paper attempts to compare the habits of the black crappie with those of the perch, with the purpose of ascertaining why the former is better suited to shallow lakes and the latter to deep lakes.

"2. The food of the crappie consists chiefly of insects, particularly immature stages, entomostracans, amphipods, and fishes.

"3. In spring amphipods and entomostracans are the chief items in the dietary. During the warmer months crappies feed largely on insect larvae, pupae, and adults, and on cladocerans. In winter adult crappies take little or no food in Wisconsin lakes.

"4. Feeding is most active at night, or in early morning and evening.

"5. Young crappies feed for the most part on copepods, cladocerans, insect larvae, and amphipods. During their first season they increase rapidly in size until the temperature of the water falls to about 4 degrees C., but grow very little during the winter.

"6. The rate of digestion in the crappie is about the same as in the perch, but less food is eaten at a time and feeding is more deliberate.

"7. In southern Wisconsin lakes, crappies spawn after the water temperature has reached 19 to 20 degrees C., or more; while the perch spawn earlier, when the temperature is 8 to 9 degrees C.

"8. During the winter crappies remain in deep water and are comparatively inactive. In spring they come inshore and remain in shallow water throughout the summer.

"9. Crappies have few parasites when compared with perch.

"10. Though perch are more abundant than crappies in the shallow lake investigated, they do not attain large sizes. Crappies are large, and, considering their larger sizes, relatively abundant.

"11. Crappies are better suited to shallow lakes than perch, because: (1) they can better endure high temperatures; (2) their feeding habits enable them to secure food more easily; and (3) they are less subject to infection by parasites."

Yellow Perch. Bean says the yellow perch is found in lakes, ponds and rivers and that it feeds upon small fishes, crustaceans, and other animal matter. "Fry are available in May and June; fingerlings from September to November. Plant in shallow parts of the waters to be stocked." The few specimens examined by Forbes (1880) showed that the young less than an inch long had eaten Entomostraca with a few insect larvae. Perch from about one to two inches fed largely upon Entomostraca but had eaten a considerable quantity of insect larvae and insects. Still larger fish had eaten nothing but insects in the aquatic stages; still other youthful perch up to about four inches in length depended upon aquatic stages of insects and small crustaceans. The most comprehensive account of the perch is that of Pearse ('20), in which the youngest perch examined (from about 1 1/6 to about 2 3/10 inches long) are stated to have fed upon aquatic forms of insects, entomostracans, small amphipods, et cetera.

Records in general indicate that the perch varies its diet according to locality, or rather according to the available food. It would appear that the adult fish is almost omnivorous. It is a fish eater of some voracity and capacity when fish that it can handle are available. The present writer has found perch gorged with young smelts, and has known them to take adult smelts four or five inches long and shiners of like size when used as trolling bait for salmon. They have been observed to take small frogs used as live bait for black-bass.

Pikeperch. Apparently no study of the life history of this important food and game fish has been made. According to Bean the pikeperch prefers lakes and rivers with clear water, and with rock, gravel, sand or hard clay bottom. It feeds upon minnows, crawfish, and insects and their larvae.

The fry are distributed in May, within a few days after hatching. They may be planted on sandy or rocky shoals in lakes and their tributaries. In some waters, at least, the pikeperch ascends streams to spawn in early spring. Since the young are planted so soon after hatching it would appear a logical procedure to plant them in the spawning places.

Muskellunge. Of the pikes only the muskellunge of Chautauqua Lake is propagated by the State Conservation Commission. Bean ('16) says that it should be planted only in that lake and other waters belonging to the Ohio basin, and that young fish may be planted in May and June near the shores of lakes.

There are no records of the food and habits of the young muskellunge.

Smelt; Icefish. Bean wrote: "This marine species ascends rivers to spawn, and has been introduced or landlocked in Lake Champlain and other lakes of the State. It is in great demand as a table fish, and is useful in furnishing food for landlocked salmon and lake trout."

There is no doubt but that the "icefish" of Lake Champlain is a permanent inhabitant of the lake. It is neither landlocked nor introduced. In Lake Champlain there appear to be two distinct sizes of adult or mature smelts, as there are in a number of lakes in Maine. Whether these two sizes are distinct species or races or merely different age classes has never been determined.

The spawning places of the Champlain smelt or icefish have never been discovered though some effort has been made to find them. But since in other fresh waters there are no known instances of smelt spawning in a lake, and inasmuch as they always spawn in a stream or waters where there is some current approximating a stream, it is believed that the Champlain fish must have similar habits. The spawning of smelts is not restricted to rivers. They will enter the smallest accessible stream for the purpose. Since the smelt or icefish of Lake Champlain is of such commercial importance it would seem highly desirable that the habits of the fish in that lake be studied, and since the smelt is in demand as a food supply for salmon and trout it would appear also of practical importance to ascertain whether the two sizes mentioned are distinct species or races or just age classes. If the first was the case the practical utility of such a determination would be according to the purpose of the stocking. If it were for human food the large size is the one which should be used. If for food for fish, particularly salmon, the small size would be most desirable; for it would always be of suitable size for the fish, whereas the large smelt attains a size which makes it a very formidable, predacious and cannibalistic fish, and one too large for food of the average salmon.

Bean wrote: "The eggs are collected in March by the Long Island station, and may be shipped in the eyed stage a short time thereafter. They should be planted in small, rocky streams tributary to the lake that it is desired to stock. Since the eggs are adhesive, they become attached to stones, sticks, and other objects, where they remain until hatched."

The transplanting of eyed eggs appears to be a better practice than to attempt to transport the tiny, delicate, thread-like fry. It has been found that a good way to handle smelt eggs is to collect them on some material such as moss, brush, or even burlap and transplant them in that shape.

Bullhead; Hornpout. The catfish family comprises several highly esteemed food fishes, some of which attain a large size, and some of which are locally regarded as game fish. However, it appears that the only species reared or distributed by the New York State Conservation Commission is the common bullhead or hornpout.

Dr. Bean did not include the bullhead or any of the catfishes in his list of the fish propagated by the New York State Conservation Commission, but later reports indicate that the Commission distributes them to some extent.

Needham ('22) names the bullhead as one of the most valuable species of Lake George. In the same report Moore says concerning the young: "Their period of active feeding begins when they leave the cover of the nest and under the protection of either one or both parents spread over the rim of the nest in quest of food. At this time they are about 10–12 millimeters long and are as black as tadpoles. . . . Their first meal consists of the minute animal organisms which are developed in the vegetation of the spawning grounds. These are the minutest of the waterfleas and crustacea together with very small midge larvae. They remain the prominent staples until the fry are about two weeks old, though by this time they do not confine themselves to the minutest forms. At about the age of two weeks the schools scatter and the individuals behave much as do the older bullheads in their food gathering, scooping up algae, debris and the like along with the animal life."

The bullhead is of wide natural distribution but it affects still waters, — lakes, ponds and "dead waters" of streams.

The Whitefishes. The whitefish family comprises a great many nominal species or races, particularly those commonly designated as "herring," and many waters of northern New York contain one or more of them.

Some of them are occasionally taken on a baited hook or on a fly. However, they are not generally recognized as game fish and are not propagated and distributed as such.

Not much is known concerning the life histories of any of the whitefishes, but the Federal Government and certain States have extensively propagated some species. Bean lists four species as distributed to some extent by the New York State Conservation Commission. These are the common whitefish, the round whitefish or Adirondack "frost fish," Lake Erie herring and greenback herring. In later reports of the Conservation Commission the tullibee is also mentioned.

Special effort should be made to study the life histories and conditions of environment of the various important species.

1. Common Whitefish. Bean ('16) wrote: "The common whitefish, probably the most esteemed of all fresh-water food fishes, is found in Lake Ontario, some Adirondack lakes, Otsego Lake, and several other lakes in the central and western parts of the State. It is an inhabitant of cold, deep water, coming to the shallower parts to spawn. It may be taken with hook and line, but is usually caught with nets. The food of adults consists largely of crustaceans, and also mollusks, insect larvae, and small fish; that of the fry and young fish is almost wholly small crustaceans.

"The fry are distributed in March and April and should be planted in the shoal parts of lakes."

These instructions concerning the planting of fry afford no advance over the procedure of many years ago.

Thirty years ago Professor J. Reighard wrote concerning whitefish in the Great Lakes ('94): "Several hundred million ova are taken annually and placed in the hatcheries, and of these usually from eighty to ninety per cent are hatched and placed in the waters of the Great Lakes, 165,000,000 in Lake Erie alone in 1888.

"This is very nearly all that is known about these young whitefish. About their food habits we know only that in captivity they eat certain species of Crustacea. Whether in their natural habitat they eat other animals in addition to these Crustacea or in preference to them we do not know. It is uncertain at what age they begin to take food, or how much they require. We do not know their natural enemies. We do not know whether they thrive best in running water or in standing water; in shallow water or in deep water; whether at the surface or near the bottom. What changes of habitat or of food habits the fish undergo as they grow older is a still deeper mystery.

"Our problem is to place young whitefish in the Great Lakes under such conditions that as large a number as possible of them shall grow into adult fish. It is clear that of one of the elements in this problem, namely, the whitefish, we know but little."

Forty years ago Professor Forbes ('83) found that young artificially hatched fish in captivity would eat certain forms of minute crustaceans, but since that time scarcely anything has been learned of the food of young whitefish under natural conditions, although some advance has been made in the knowledge of the food of the adult fish.

Hankinson ('14, '16) records the food of little whitefish, 3 to 3.5 inches in length, which were found in a lot of small "herring" of similar size on a shoal of Lake Superior. He said that he was unable to find in the literature a record of whitefish beyond the fry stage as small as those taken at Vermilion. The young whitefish were found to be eating entomostracans freely, and this appeared to be the chief food of those collected. Midge larvae (*Chironomus*) were found to be taken by them in important numbers.

2. Round Whitefish; Frostfish. Bean ('16) says that the round whitefish is found in the lakes of the Adirondack region and that its food habits are similar to those of the common whitefish. "The fry are ready for distribution in March and April, and are usually planted by the Commission in the waters from which the eggs were collected." No definite instructions are given for planting the fry, and there appears to be no specific information concerning the food of the fry. Very little information concerning the habits of the species is available. In certain waters, as in Maine, this species ascends tributary streams of lakes to spawn. How long the young remain in the streams after they are hatched does not appear to be known. Basing the recommendation, however, upon the fact that the fry's first existence is in the stream, other things being favorable, it is best to plant fry of frostfish in tributary streams.

Hankinson ('16) states that this species was found common on the deeper part of the shoal near Vermilion (Northern Michigan). Those taken were of edible size, a little over a foot long. Two typical specimens opened had been eating principally amphipods; one had these only in its stomach, and the other had miscellaneous insect remains in addition to them.

3. Lake Erie Herring. According to Bean this species is found chiefly in Lake Erie. The fry are ready for distribution in March and April and are usually planted in the waters from which the eggs are obtained.

4. Greenback Herring. Bean says that the Greenback Herring occurs in Lake Ontario and Cayuga Lake, and that the fry are ready for distribution in March and April and are usually planted in the waters from which the eggs were collected.

5. Tullibee. The tullibee is the whitefish formerly abundant in Onondaga Lake and common either as a native or by introduction in Oneida Lake. Bean ('03) quotes from James Annin, Jr., on the spawning of the tullibee in Onondaga Lake as follows:

"They generally commence running up onto the shoals about November 15 and the season extends into December. They come up to the banks or gravelly shoals and spawn in from three to six and seven feet of water."

This account would indicate that newly hatched fry should be planted in such places, provided they have been found to afford similar conditions to those of the natural spawning beds.

There appears to be nothing definitely known concerning the life history of this fish.

Procedure for Planting Young Fish. The method or technique of planting fish as described by Bean ('16) pertains mainly to trout and streams, although some of it applies to standing waters as well. As the present writer has had but little experience in the actual planting of fish he attempts to add nothing to Bean's instructions and accordingly extracts therefrom the most important items.

Essential Preliminaries. "Plans for stocking should be made during the driest part of the preceding season. Only streams or parts of streams that have not then dried up or become stagnant should be considered in the plans for future planting. Every detail regarding the adaptability of the stream or lake for the fish that it is desired to plant should be carefully considered. Foresight in this direction will save many fish that otherwise would be lost."

Planting Points and Food Supply. "The two chief requirements of young fish are protection and food. They need protection from predacious enemies, freshets, droughts and disease. In general, for stream-inhabiting species, the headwaters furnish the most suitable planting points. Here the larger fish are not apt to be present to prey upon the fry. Freshets are not so strongly felt there, and are less likely to wash the small fish downstream. Moreover, the chances of pollution are much less. Care must be taken, on the other hand, not to plant the fish in streams or headwaters which may dry up in time of drought. For the young of lake fish the most favorable situations are generally the shallow waters near shore, or on shoals or reefs. In either case, whether dealing with brook fish or lake fish, it is well to discover, if possible, the natural spawning beds, and to plant the young in or close to such places; for it is reasonable to suppose that each species has come to choose for its spawning grounds the places that are most suitable for its young to hatch and live in. These situations are likely to be supplied with the natural food that the young require. As the fish grow they will gradually work their way into the deeper and wider waters inhabited by the adults.

"While we have only a meager knowledge of the food of fish at the earliest periods of their lives, we know in a very general way what the adults of the commoner species feed upon. It is of particular importance therefore, when introducing any species into waters where it has not occurred previously, to ascertain whether a suitable supply of its natural food is available."

Care During Transportation. "The fry and fingerlings of most species are distributed in spring and early summer. The cans containing these young fish are accompanied from the hatcheries by a messenger, who cares for them during the railway journey. The water in the cans must be kept constantly aerated, so that the fish will not suffocate from lack of oxygen. Unless special apparatus is provided, this is done by hand, water being dipped up from the top of the can and allowed to fall back from a height. Such attention is required at least every half hour. The water must also be kept cool, with the use of ice, if necessary. The applicant is notified by telegraph on what train the fish will be shipped. If he does not meet the train, they cannot be delivered, but are carried on by the messenger to the next station where an applicant awaits a shipment.

"The same care is required during the journey from the railway station to the streams that is given by the messenger of the train. Under no circumstances must the fry or fingerlings be kept in the cans over night without attention. It is necessary to take them directly to their destination and plant them at once. They should be protected as much as possible from jarring while being transported by wagon, to prevent injury to the young fish from being thrown against the sides and bottom of the cans."

Importance of Water Temperature. "Just before actually placing the fish in the water, attention must be given to the temperature of the water in the can and in the stream. If this vital point is neglected, the entire planting may be for naught, for a difference of only a few degrees between the two waters will kill young fish. A twenty-five cent dairy thermometer will show whatever variation there is. However small the variation may be, the temperatures must be equalized by dipping water from the can into the stream, and from the stream into the can, a little at a time. Another method is to stand the can in the stream, but this takes much longer." Doing both at the same time would facilitate the equalization of temperature.

Planting. "When the temperature is right, the can may be emptied. The fish may be dipped out, or carefully poured from the can. In the latter case, the mouth of the can should be held no more than a few inches above the stream, so that the fry will not be jarred by the impact of the water. The fish should be spread out as much as possible, some being planted in one place, and others a little farther away. No more than 500 fingerlings or 2,000 fry should be planted per mile in a small stream. The food supply will be in danger of exhaustion in over-stocked waters."

Artificial Stream Pools and Side Pools. "One of the very best means that can be adopted for the protection of the fry of stream fish is the building of artificial stream pools. These are formed by damming up the headwater rivulets and little spring creeks. A number of dams, built of loose rocks, logs or boards, may be advantageously placed a short distance apart on the same stream. They not only insure a good water supply for the young fish in dry seasons, but also prevent them from being swept away by spring freshets. They also largely increase the area in which the natural food supply may grow, and over which the fish may forage for this food. By remaining in these pools near the headwaters, the fry gain security from the larger predacious fish that lurk downstream. After attaining a suitable size, however, they will of their own accord seek the lower courses. Probably in most cases the stones or other materials for building the dams may be found on the spot. The structures need not be more than twelve or fifteen inches in height. The tops of the dams should be as narrow as possible, and the water should fall over them in at least one place, in order that such fish as trout may leap over the obstruction without difficulty in ascending the stream to spawn in the fall. The beaver dams in the Adirondacks make stream pools on a large scale, and have greatly improved the trout fishing on the streams where they are located.

"Side pools may be formed on large streams either by excavating suitable basins near the streams and diverting water through them, or by taking advantage of natural hollows and basins. The inlet from the stream and the outlet of the side pool should be screened to prevent the entrance of fish from the stream, which would prey upon the fry in the side pool. These pools, if sufficiently large, will provide enough natural food for a considerable number of fry. The fingerlings should be allowed to run into the main stream in the fall. On the headwaters of small streams, where large fish are not found, pools of this sort, that will require no screening, can often be made at small expense, and the fry in them will require no attention. Shade can easily be provided on the banks of side pools by the planting of willows and black alders. A few large rocks under which the little fish can hide and boards supported from the bottom on stones, and weighted down with rocks to prevent floating away, will complete the arrangements."

This may be a convenient place to call attention to a method of planting brook trout which was adopted by the Massachusetts Commission in 1920. Mr. W. C. Adams ('20) writes: "A method of distribution new in Massachusetts was adopted this year,— the planting of eyed eggs in wire baskets for hatching in streams which it is desired to stock.

"The trout ridd, or artificial nest, has had its chief development in Europe, where for years it has been the means of stocking the inaccessible mountain streams. The method therefore has been thoroughly tested.

"The first requisite for success is to make the plants under the proper conditions. A long stretch of stream is required, spring-fed to keep it free from ice and to give a suitable temperature. It should be shallow with a fairly good current and numerous shallow eddies, but not many deep pools which would harbor large fish.

"The eggs are placed in wire baskets or trays, containing about two square feet of surface, built of heavy mesh wire of such size that the eggs will not fall through. The proper age at which the eggs should be planted is from one to two weeks before they are ready to hatch. They are spread evenly in the baskets, in numbers varying from 500 to 1000 to the square foot. The tray is placed in the stream, set on small wooden uprights forced into the bottom of the stream and held about two inches above the bottom, so that the water entirely covers the container and its contents. The flow should be such as to give complete circulation in every part of the tray. After the basket is placed in position it is protected and concealed by covering it with brush or evergreen boughs in the form of a lean-to over the stream.

"As the eggs hatch the fry drop through the mesh of the basket into the silt, and lie quietly on the bottom until they begin to feed. When that time comes they rise and scatter far up and down the stream in search of suitable feeding grounds. This simulates closely the natural method of propagation."

REGULATIONS FOR PROTECTING FISHERIES

In restocking waters, having ascertained to which kinds of desirable fishes the waters are suited and having stocked them with the number which the conditions warrant, the main problem then is that of regulation, conservation and the maintenance of a supply commensurate with the demand made upon it. To these ends, for many years it was a common custom to close stocked waters for various lengths of time for the purpose of giving the fish time in which to grow and establish themselves.

Closing Stocked Streams. In many instances streams tributary to lakes or to larger streams, have been permanently closed, upon the assumption that those tributary streams were nurseries for the larger bodies of water. The majority of cases of both lake and stream tributaries pertained to the brook trout, although occasionally other species were so treated.

In some instances of temporary closure the benefits of it have accrued to a few individuals instead of the many for whom the benefits were intended. The accumulation of trout of several years have been fished out by those who were able to get the best chance to fish, in the first few weeks of the open season. The policy or law of the state usually is to stock public but not private waters, but in such instances as just mentioned, the closure has practically made the stocking a private one. The state has thereby been put to considerable expense to produce fish for a few individuals. Hence the dissatisfaction amongst other trout fishermen because those first on the brook had "beaten them to it."

In the cases of permanent closure there often appeared to be a decrease rather than the looked-for increase of trout. So the question arose as to the practical use of closing such waters.

Aside from the inequitableness referred to, the question of the temporary or permanent closing of waters involves several other considerations, one of which is economy. The fact that a body of water will support a certain amount of organic life and no more, has been emphasized in this publication, and in others. A brook, for instance, is capable of producing food enough to adequately sustain a stock of brook trout in proportion to the area, if in other ways suited to the fish. The size attained by the trout depends in a great measure upon the quantity of its food supply. If, as elsewhere indicated, the trout area is over-crowded, the fish will not attain the maximum average growth which they otherwise might attain. Investigations or ecological studies of trout have not yet reached the point where we can correlate the available food supply with the exact or even approximate number of fish that should be planted in a given area. It is usually the custom to consider the size of the stream and *guess at the number of fish which should be planted,* in order that it may be adequately stocked. At least that is the custom when other influences are not brought to bear. In any event the allotment has been in the past, and continues to be, when possible, a very liberal one, and one that is likely to comprise more fish than the area can sufficiently provide with food. In a discussion of this subject Dr. Nathan Fasten, of the Oregon Agricultural College, calls attention to a possible result of closing a stream (Fasten, '22). He says: "My observations along this line have convinced me that this [closing of a body of water to fishing] is an erroneous practice. In the first place, closing down a stream makes for a rapid multiplication of fish so that the available food supply soon becomes inadequate to maintain all of them. A fierce struggle for existence ensues in which many of the weaker, but nevertheless desirable fish, are killed off. Even those that remain appear to be starved for lack of food."

In the present writer's experience, while some of the larger fish may appear more or less emaciated, the general tendency under overcrowded conditions is for the fish to remain small, and to attain breeding maturity while yet small, and consequently produce fewer or inferior progeny, although it is conceivable of the food supply becoming so depleted that the trout would resort to cannibalism and even starve.

Dr. Fasten mentioned another undesirable condition which might arise from congested conditions within a stream. That is, a rapid spread of any parasitic infection which happens to make its appearance among the fish, and he indicated that parasitism might be engendered under "closed down" conditions, in that the undisturbed shores would afford a habitat for fish-destroying birds and other animals which not only kill large numbers of fish, but may also be the means of disseminating various parasitic organisms among them.

Protective Methods. Bean ('16) wrote: "The strongest ally of stocking is protection. Without the latter, the former will quickly be nullified. The game protective force is constantly on duty to prevent illegal fishing in all of its forms, and accomplishes results which place it in the front rank among similar organizations in this country. It should be understood, however, that fully effective protection is dependent upon public cooperation. The force of any law is determined largely by the sentiment of the community to which it applies, and in a community which does not countenance game law violations the violations are relatively few. In accordingly behooves everyone interested in better fishing to foster the development of a clean and sportsmanlike spirit regarding the observance of the fishing laws. Without such moral support and active cooperation on the part of sportsmen, the 450 square miles which every protector must police on the average cannot be thoroughly supervised. It should be realized by those who are doing the stocking that it is quite as important to effectively protect their fish after they are in the water as to place them there properly at the start."

Laws intended to protect fish should be based upon positive knowledge concerning the fish to be protected. Unless they are framed in accordance with such knowledge, no matter how rigidly and thoroughly they are enforced, they are liable to fail of their object, and even result in harm to the fish for the protection of which the law is enacted.

It is generally conceded that fish should be protected during their breeding season. Yet there are those who maintain that it is no more harm to kill a fish during that season than at any other time. They say an intensive fishery at any season destroys just as many eggs and consequently progeny as if they were all caught in the breeding season. This is false reasoning as applies to fish in general. It is true that commercial fisheries for certain kinds of fish are conducted profitably only at the time the fish are on the way to the breeding places, and if the fishery were prohibited none of those fish would be available for food. But there are many examples of depleted fisheries which are attributable to too intensive fishing at that time.

It is easily seen why this is so. It is quite clear that if no fish are produced to take the place of those caught the future supply is reduced. Fish hatcheries are supposed to remedy this situation.

But what is to be done when breeding fish are not obtainable to provide the eggs to hatch? Breeders must be maintained or the fish will literally as well as figuratively "go to pot." The logical conclusion would seem to be that there must be sufficient breeding fish left to maintain the supply.

Mention has already been made of the failure of the egg supply of a certain fish and the impending failure in the case of others. Another instance is related by E. W. Cobb, Superintendent of Fisheries of Minnesota, in an article entitled "Last Stand of Pike-perch in Minnesota Lakes." He wrote ('22): "Let us look for a time at the history of this fish during this period [past years] and see as nearly as possible what the facts are today. In spite of the efforts being made for its increase the species has rapidly fallen off in numbers until today many of the States in which it was native can no longer secure eggs and others can secure them only in limited numbers. . . . The southern part of our State (Minnesota) is now and has been for some time in such condition that artificial propagation would be impossible except for the supply of eggs taken in the northern part of the State. The sections from which eggs can be secured have narrowed down to the northern part of the State, and the lakes here are more accessible and more heavily fished than the more southern lakes even five years ago. . . . Notwithstanding these efforts it is realized that more must be done if the supply is to be maintained. We now have no really inaccessible waters and a constant procession of tourists pass from and through southern Minnesota to the north where fishing is good. Many come from the West, and from as far north as Winnipeg. Besides this the people from villages and cities as well as those living in the immediate district spend days and weeks by the lakes which could not be enjoyed but for the auto which is available to nearly all. In fact a veritable tidal wave of people seems to be sweeping over the wilder sections of the State, and at times to be about to destroy our best fishing grounds.

"The question is of course, what shall we do about it? Shall we increase our efforts in behalf of those lakes now containing a good supply even though it might seem at first thought to be to the detriment of lakes further south? It will not benefit our southern lakes to follow a policy which will eventually result in doing away with the only available supply."

As remarked elsewhere, the number of anglers cannot be controlled but their operations may be in one way or another. But such regulations sometimes appear impossible owing to conflicting interests, as in the above instance of north and south Minnesota. Those interests must be harmonized or failure of the fisheries is inevitable. Harmony is attainable only through enlightenment of the conflicting interests as to the facts, and the real facts become available only by acquiring a full knowledge concerning the fish and its "interests." The fact may prove to be that southern waters were fished out in spite of efforts to maintain the fishing. That is probably not the whole cause of the present depletion. If it is the whole cause, in spite of the "past intensive" efforts to maintain a stock, the pikeperch in Minnesota surely has its "back to the wall." The method of handling the situation must be modified in the light of positive knowledge concerning the lakes and the fish, and by regulations of the fishery.

Without basic knowledge concerning all conditions pertaining to fish and fisheries, legal regulations and restrictions, while they may sometimes help, in the long run often prove ineffective. A regulation that may be effective in one locality may not be in another; or one that will apply to one kind of fish is quite sure not to apply to another even though it be a closely related form. Yet one general law is often made to cover a whole group of fishes, such as the blackbasses and other members of the sunfish family, or it may be the pikes or even the trouts.

Concerning the trouts it may be said that a law protecting the brook trout in its breeding season will not afford protection to spring spawning trouts unless the closed season is extended to cover the breeding seasons of those forms.

There are often purported protective laws applying to fish at other seasons than the breeding season. These may pertain to place of capture or method of capture, or something else. Some of these laws frequently appear to favor one or another class of fishermen, as for instance the restriction to fly-fishing, which meets with objections from the users of natural baits. The custom of fishing with bait in certain places where fish are known to congregate at some season of the year has been a matter of controversy among fishermen in some localities, and laws prohibitive of deep water or so-called "plug fishing," and "advance baiting" have been enacted.

Laws have been passed restricting the fishing for certain fishes to a single hook, thus eliminating multiple hooks and gang hooks. In some instances these have been repealed through the influence of fishing tackle dealers. So we might go on and recite a multitude of laws which do not always fit the case and seldom meet with general approbation.

So, to repeat, appropriate laws and regulations must always be based upon accurate knowledge of the fish and the conditions affecting them, accompanied by education of fishermen whose interests appear to conflict.

There must be regulations even though they apparently affect some people or some localities disadvantageously. The adage, "You cannot eat your cake and keep it too" is well stated in the words of a former Federal Commissioner of Fisheries, thirty years ago, (McDonald, '94, p. 16): "We must not, however, be unmindful of the fact that the prosecution of the fisheries without reasonable and necessary restraints, is sure in the end to make adequate reproduction by artificial methods impracticable by obstructing or shutting off the sources of egg supply. Protection, therefore, and reasonable regulations as to the times and methods of fisheries is just as essential for the maintenance of our fisheries as is the largest measure of artificial propagation."

Legal Sizes for Catching. Bean ('16) says: "Inquiries indicate that there are many persons who do not understand the exact significance and necessity of the six-inch law for brook trout, and of similar regulations regarding the size at which other species may be taken. Until an individual of a given species has reached the prescribed size, it has never spawned; and if all the individuals were caught before they had arrived at the spawning age, it is perfectly plain that the complete extermination of the species would be a matter of only a short time. It is therefore to the interest of every angler to see that under-sized fish are not destroyed. Every food and game fish should have a chance to spawn at least once before being taken."

The principle conveyed by the foregoing paragraph is sound in its general application, but it seems to the present writer that the size limit for trout, at least, is one for local regulation, or rather in imposing a size limit local conditions should be considered. In some localities the brook trout, and possibly other species, are known to attain maturity at a size below the legal limit of six inches, and never reach a much larger size. In other instances they attain a much larger size than that legal size limit of capture before maturity.

Under favorable conditions trout grow rapidly, but there is no way of answering definitely the frequent query, "How long does it take a trout to grow to a certain size?" According to circumstances a trout may attain in two years only three or four inches in length, or it may attain ten or more inches. Under certain conditions, as in circumscribed localities like a small brook, trout often reach maturity when only four or five inches long and still bearing the marks of a young fish. Again, mature trout have been seen of not over five or six inches in length in which these marks of youth had nearly or quite disappeared, and the male fish was a facsimile of its larger brother of the lake. Also trout of nine and ten inches still immature have been seen in lakes and streams of considerable size. For example, "large" trout, sexually immature, were noted on October 18, 1916, in a large pool below the dam at the foot of Matagamon Lake, East Branch of the Penobscot River, Maine, by the present writer who caught 14 trout from 6⅞ to 10¾ inches total length, all of which were immature. Apparently they never had spawned, for there was no second crop of visible eggs as is usual when the fish have spawned once. Six of the trout were males from about 9 to about 10¾ inches total length and eight more were females ranging from 6⅞ to 10½ inches total length.

Writing of trout in the Connecticut Lakes region in Northern New Hamsphire, the author (Kendall and Goldsborough, '08, p. 53) said: "Every stream and pond in the region contains more or less trout, varying in size according to the body of water and in number according to the accessibility and ease with which the water is fished.

Many of the little mountain brooks literally teem with small trout, frequently too small to be legally caught, yet some of them are adult fish and probably will attain no larger size. Small brooks of whatever character, from mountain rivulets to sluggish bog brooks, seem to contain trout. Hundreds of these trout are caught every year, and it is a question whether any harm is done thereby, for while a few may reach the lakes or river and become large fish, most of them remain in the brooks, reach maturity, and spawn while still small fish."

Need of Fish Preserves. There is already an actual failure of the egg supply of some species of fish and there is an impending failure of the supply of still others. The most serious problem appears to concern the landlocked salmon, lake trout and brook trout in the Eastern states, and it has been seen that the pike-perch is similarly a matter of concern in Minnesota. Like conditions with this latter species and even others may obtain in other localities. If such conditions are not already apparent they probably will be sooner or later.

Of course, it is quite obvious that the species of most limited natural distribution, are the ones most imminently threatened. Already one or two such species have been practically exterminated. The case of the landlocked salmon has already been cited and emphasized. The lake trout and brook trout are more of local than general concern just at present. But it may be considered as significant that the United States Bureau of Fisheries and the New York State Conservation Commission now buy many of the brook trout eggs which they hatch and distribute, from private or commercial concerns. Probably this is due to the fact that, while commercial trout eggs are expensive, the cost is less than it would be to go to the remote waters where the fish may still be common. The immediate wild waters, as has been shown, do not now afford an adequate yield. The trouble encountered and problems that arise concerning brood stocks, eggs and young trout in many hatcheries, taken into consideration with the receding sources of supply of wild eggs are surely ominous and merit careful thought.

It is quite noticeable that most of those species which are not stripped and hatched "artificially," but which are allowed to breed naturally, and are protected and assisted in the process, afford fewer and less serious problems of maintenance of the stock, than do those species previously cited, and some of them are more amenable to pond cultural processes. The foregoing facts give rise to the warning that something in the direction of conservation of the egg supply and the breeding stock must be done as soon as possible. To that end the suggestion here made is that the most practicable measure would be the establishment of natural sanctuaries for each species concerned, similar in purpose to game sanctuaries. In other words a natural body of water might be selected, which would afford sufficient area and volume, and adequate conditions for the maintenance of a brood stock of each species with which the State is concerned. The selection should be based upon a scientific examination, that all essential conditions may be assured. In such waters no fishing should be allowed and the waters should be preserved for fish cultural purposes. It would be possible to manage such a reservation so that a future egg supply would be practically permanent.

Game Fish versus Food Fish. In 1903, an agent of the United States Fish Commission canvassed the interior waters of the State. In his report (Cobb, '05) he said: "New York is dotted with numerous lakes, many of them such as Oneida, Champlain, Seneca, and Cayuga, of great extent, while there is a veritable network of rivers, creeks, and canals throughout the State. The principal aim of the authorities has been, as far as possible, to confine the fishing in the interior lakes and streams to sportsmen, who are attracted not only from all parts of New York, but from other States and even from foreign lands by the excellent fishing afforded in these waters. Such pleasure seekers are usually liberal, and the sums expended by them net a larger profit to the community than would be obtained by the unrestricted use of fishing apparatus on the part of local fishermen. It has been estimated that the sportsmen leave behind them, in the hands of the railroads, hotels, guides, boatmen, etc., several million dollars each year."

In this bulletin it has been previously indicated that in the majority of interior waters the angling sport has come to be regarded as of paramount importance, although the general public "pays the freight." Without doubt there are large numbers of anglers but there is no angling license fee. As concerns productive game fish waters under present conditions, it is no doubt true, as claimed, that the game fishes of the inland waters of the State are a far greater asset than a commercial fishery in those waters would be. But there are over fifty species of fishes inhabiting the interior waters of the State which are or might be important food fishes, and many of them are not accounted as game fishes and do not attract the angler. Such fishes are more common in the larger lakes rather than in the streams and small ponds. As has been shown, only a few of the fish indigenous to the State are propagated or raised and distributed by the Conservation Commission.

It is contrary to law to fish in many of the interior waters by any method other than with hook and line (figures 42, 43, 44). Under present conditions this is doubtless a good provision so far as the fish which can be taken by those methods are directly concerned. But many excellent species of food fish cannot be so taken effectively, if at all; and in practice these are usually taken illegally, for licensed netting is restricted or forbidden in certain waters. Besides these species there are others, so-called coarse or cull fish, which are not generally held in favor as food fish, and some of which are reputed to be harmful in one way or another to game fishes. Their destruction has often been advocated by anglers. Most of those species are really good food fish, and, as a matter of fact, are locally esteemed as such.

Fig. 42. Angling in the Oneida River, near Caughdenoy, New York.

Fig. 43. Angling in a meadow trout stream in Erie County, New York.

Fig. 44. Catching yellow perch through the ice. Oneida Lake, New York

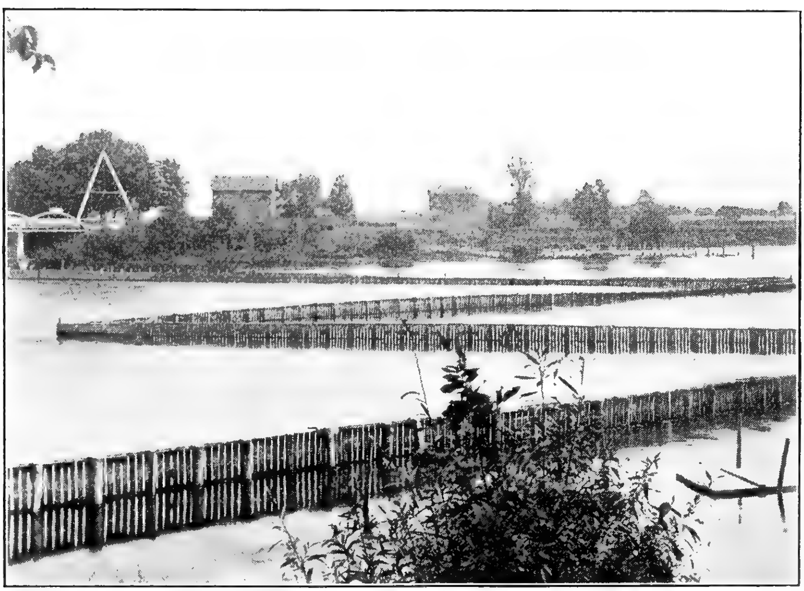

Fig. 45. Eel weirs, Oneida River, near Caughdenoy, New York.

In connection with some waters, whether or not it is economy to restrict fishing to one or two game fishes when the waters abound with other fishes valuable for food, or where, if once numerous but now depleted, they can be replenished, is a question.

Food resources are of vital importance in these days, as is recognized by all. It would seem that although a lake may be yielding a good crop of game fishes, which represent value in dollars and cents, if that lake can be made to yield a supplementary crop also representing monetary value, it would be good business to develop it, at least for more or less local consumption, according to the magnitude or character of the fishery, providing it is not detrimental to the principal crop (figures 42, 44, 45). Moreover attention has been called to the fact that the general game fish supply is decreasing and its complete failure is only a matter of time unless something constructive is done to check the decline. The interrelations and interdependence of animal life in a body of water has already been discussed to some length in this bulletin, as well as in many other publications, and it should not be necessary to repeat it here; but it may bear repetition to state that the decline of game fish may not be wholly attributable to over-fishing, but that possibly it has been hastened by an over-increase of some other species which the decrease of game fish has permitted, and when nothing has been done to check the less desirable kinds. In some instances, too, the over-increase may have been reflected at last upon those species so that there is general depletion. So, as has been shown, readjustment of the balance is necessary. To ascertain the facts, in order to attempt readjustment, calls for an investigation. It is rapidly becoming expedient that an effort at readjustment be made, for so far as the sport of anglers and food supply is concerned it becomes not only economic waste but in some instances possible obstruction to the conservation of some of those fishes for the preservation of which present laws are intended.

It would be both an economical and a conservative measure as concerns the game fish, if some means could be devised by which the people of a region could get the benefit of such surplus fish. Formerly certain privileges in that direction were granted, and to some extent the same may obtain today. Nearly twenty years ago J. N. Cobb ('05) wrote: "Whenever possible without injury to the sport fishing, the State has permitted the use of nets to some extent, principally for the purpose of reducing the abundance of the commoner species of fishes, which when in excessive numbers, do serious damage to the game fish by devouring spawn and fry. It has been an exceedingly difficult matter to guard waters so extensive, however, and as a result there is much illegal fishing." Undoubtedly in some localities there are those who get the benefit of any fish that can be caught by proper or illegal means, and under present conditions enforcement of the laws is difficult, yet it does not seem to be a rational or logical procedure to deprive everyone of the opportunity to augment the food supply because a few abuse the privilege, especially when by a study of conditions, enlightenment of public opinion concerning the exact situation might become possible, and thereby abuse of the fishing privileges might be reduced.

The present comparatively ineffective efforts to save the game fish is a matter of concern to many, but there are many more who have no interest in those fish or any other fish, as game fish. Their interest is in the fish as a source of profit or food. Some of them, perhaps many of them, in no way, so far as they can see, share in the "millions" which anglers spend for their sport. There is therefore a conflict of views between them and the angler which has given rise to the present vexed questions. Bean ('11) said: "It is unfortunate but true, that the life of the inland lakes of New York, numerous and important though they are, is as little known as that of some of our remote possessions. New York ranks among the greatest of the states in the value of its fisheries and its waters contain undeveloped resources of unusual importance. We know little more than the names and spawning seasons of our common fishes. The interrelation of species in their effects one upon the other is almost a sealed book to us. In fish culture the State is occupied with only about thirty species [including marine] and these are under observation for the most part at the spawning season only. What is going on in the open waters of our streams and on the bottoms of our lakes is little understood, and yet it is of vital importance to the success of our work. The State ought to devote more time and money to the study of its natural aquatic resources. Such investigations would yield unexpected and most gratifying returns. It is time that the importance of the fisheries to the general public as well as the angler was fully recognized and acknowledged."

It is a recognized fact that the general public bears the expense of fish culture and the burden of protection of the game fishes. It is true that the anglers are a minority of the general public, and being a part of a whole, there should be no conflict of interests as concerns public welfare. The anglers have undisputed rights, but the majority have certain rights also, so far as the management of the public resources is concerned. One of its particular rights is that of deriving some benefit from the expenditure of public money. This is an important fact which appears to have often been overlooked, disregarded, or underestimated. While this may not be the proper place to say so, it is high time that it be said, that this just relation of the whole of the people to a part of the people, is an imminent economic problem of which the State will have to take cognizance in connection with the interior fishing waters.

The benefit to be derived by the fish-eating but non-fishing population from public money well spent in development of the resources of the interior waters lies in the products of that development. Many of the largest lakes of the interior once contained an abundant supply of whitefishes of several kinds and some of them perhaps do even today. Those that do not might be capable of such development through intelligent management. While the State has propagated some of them and planted them in interior waters, they have usually been subject to the law restricting the method of capture to ordinary angling methods. The question concerning these fish came up during the late war.

The Seventh Annual Report of the Conservation Commission, State of New York, for 1917 (pp. 45–47), says: "A careful study of the work that has been done during many years in the stocking of many lakes with whitefish leads to the conclusion that the policy of the State with regard to this fish has never been thoroughly worked out. While the whitefish is not to be classed for a moment with a number of other species as regards destructiveness to spawn of other fishes, it nevertheless is a fact that the whitefish does eat spawn and young fry in lakes inhabited by trout. Moreover an examination of a number of whitefish stomachs indicates that in some of these lakes the principal food of the whitefish is the same as that of the trout existing under similar conditions. Thus it is a competitor of the trout and in trout lakes that have been intensively stocked with whitefish the latter is unquestionably being fostered to the detriment of the trout. In such lakes, however, most of which are in the Adirondacks, there is a more serious argument against practices heretofore in force. Though the State has for years been stocking these lakes with whitefish, it is nevertheless contrary to law to take them, other than in the Great Lakes, except by angling. In a limited number of the Adirondack lakes whitefish are caught by angling, but in many others they are not taken by angling at all, and thus for all practical purposes are given protection throughout the year.

"It is important that the entire policy with regard to whitefish be revised and that the taking of these fish commercially be permitted in some of the lakes where they are abundant, thus making it possible for the public to obtain some benefit for the expenditures which have been made in stocking these waters. In other lakes, where it is not advisable to permit commercial fisheries operations, it would seem that the whitefish should be able to maintain themselves by natural reproduction in sufficient numbers to compensate for all that may be removed by angling alone, and that annual stocking hereafter is unnecessary in those waters. In other words, the Commission believes that the whitefish product of the hatcheries should be planted almost exclusively in waters which are fished commercially. Plans to this end are being developed.

"The Adirondack frostfish is one of the minor whitefishes which is abundant in some of the Adirondack lakes. It has been propagated by the State for years. It is not taken by angling, however, and it is unlawful to fish for it by any other method. It therefore seems futile to continue the propagation of this species unless some means are found whereby they may be caught and utilized as food fish. The tullibee, another species of whitefish, has been extensively propagated at Constantia and yet the public has derived no benefit from the expense thus incurred. For this reason the work was discontinued during the last spawning season. Attempts are being made by the Commission, however, to develop a method for establishing and regulating a commercial fishery for this species and if they are successful its propagation will be resumed."

A few years before this, the whitefish question arose in Vermont. A legislative act of 1912 gave the Commissioner of Vermont (Titcomb, '14) "power to investigate the waters of Lake Champlain with a view to ascertaining whether it is practicable to take whitefish, commonly called shad, without seriously depleting the waters of fish ordinarily taken by the angler. With a view to carrying out this investigation, Dr. H. F. Perkins of the University of Vermont, was placed in direct charge of the investigations. A professional fisherman from Lake Erie was employed to operate nets.

"Through the courtesy of Hon. Hugh M. Smith, United States Commissioner of Fisheries, and Dr. H. F. Moore, Chief of the Division of Scientific Inquiry of the Federal Bureau of Fisheries, it was agreed that the investigation should be a joint one, that the survey might not only be one of investigation as provided by the state law, but in connection therewith that a biological survey of the lake should also be made."

In another paragraph the report says: "The investigations have not been completed. At the close of the present fiscal year Dr. Perkins is conducting a biological survey and further investigations connected with the whitefish inquiry, under the auspices and financed by the United States Bureau of Fisheries."

The United States Commissioner's report for 1914 refers to the work in a few words as follows: "A biological and fishery examination of Lake Champlain, commenced during the year in cooperation with the Vermont State Fish Commission, was suspended at the close of the summer, but will be concluded during the next fiscal year. It has as its primary purpose the determination of the feasibility of establishing a commercial fishery for certain species of fishes without detriment to the sporting interests on the lake which are a valuable asset to the people of Vermont and New York."

In subsequent reports there is no further mention of the biological and fishery examination of the lake. It apparently ended in 1914. Thus about the only conclusion reached by the survey was the conclusion of the survey. But the Commissioner of Vermont expressed the belief ('14, p. 69) that there were not sufficient whitefish in Lake Champlain to warrant a special commercial fishery for them, but further investigation might demonstrate that it was feasible. He went on to say: "It should be proper to take from Lake Champlain the largest number of fishes of all kinds that it is possible to annually remove without depleting the stock which makes the lake itself most attractive to the inhabitants of the border states, and which is an especially valuable asset to Vermont, in attracting anglers from abroad."

While it might be advisable to cease to plant whitefish in trout waters to which whitefish were not indigenous, it would seem desirable to have some sort of arrangement by which these fish might become available for food, at least locally. Elsewhere in this bulletin the statement was made that no small body of water can afford an unlimited supply of food fish. If a market fishery is carried on in inland waters for sport fish, it is impossible for the stock to be naturally maintained. But under proper regulations such waters might be capable of yielding a limited, though appreciable and appreciated, amount of food fish without damage to the sport fish.

In northern Maine a chain of lakes contained, besides indigenous lake trout and brook trout and various " coarse fishes," three kinds of whitefish, all of which, excepting the trouts, were very abundant in 1903 when the present writer visited the region.

All three whitefishes ascended the streams connecting the lakes to spawn. In this locality no commercial fisheries were permitted, but occasionally the native French inhabitants were allowed to net the whitefish under restrictions during the spawning runs. In reporting upon the conditions as observed in the region the present writer said: " The fishing as now regulated is chiefly important to the sportsman, but the abundance of whitefish in a lake system of such extent suggests a possible commercial fishery under proper regulations, which would afford the inhabitants of Aroostook County at least, a delicious fish for the table, both fresh and cured. A limited net fishery, restricted to the summer months and to certain localities, would do no more damage, if as much, as is done by fishing on the spawning beds, which is now permitted." (Evermann, '05, p. 104.)

The State propagated whitefish, obtaining most of the eggs in this region, and distributed them in various waters of the State, with what object it is difficult to see, since the fishing was almost wholly restricted to hook and line, and but few were caught in that way. Now the sport fishing in the same region has greatly declined, for the same reason that it has in many other waters of the Eastern States. This subject need not be dwelt upon.

In New York State there are a number of extensive lakes some of which support a relatively large number of fishes other than game fishes, but as the report previously quoted states, they are not generally allowed to be caught by other than angling methods.

As examples of such lakes, let us take the largest two outside of the Great Lakes. One of these is wholly within the State borders. The other is of interstate as well as, to some extent, of international interest.

The first is Oneida Lake. As indicated by Adams and Hankinson ('16) the game fish as rated by the president of the Anglers' Association of Onondaga, in the order of preference, are: Small-mouth blackbass, pikeperch, large-mouth blackbass, yellow perch, pike (" pickerel "), and bullheads. The food fish as similarly rated by a fish dealer at Brewerton comprised a dozen or so species listed in classes: (1) eel, pikeperch, yellow perch, bullheads and pickerel; (2) sunfish, black and red-fin suckers; (3) rockbass; (4) fork-tail catfish; (5) Oneida Lake whitefish or tullibee.

Their list of fish inhabitants of the lake includes at least 20 species of really excellent food fish, some of which are locally of little or no value as food, but which elsewhere are locally utilized.

Cobb ('05) indicated that other than some sorts of hook and line devices, the only apparatus employed in the commercial fishery of Oneida Lake in 1903 were seines, seven of which were in use. The only fish reported as caught by that means were 600,000 pounds of suckers valued at $12,000.00.

The total yield of all kinds of fish of the commercial fishery of that year amounted to 708,993 pounds valued at $18,088.00. The catch of suckers alone by other than hook and line methods amounted to over 87 per cent of the total catch.

In the face of these figures it would seem that Adams and Hankinson were justified in their opinion: "Clearly such a large lake should not be managed solely to the angling interests, but should produce an abundance of fresh food fish for this part of the State."

The second example is that of Lake Champlain. Evermann and Kendall ('02) listed about 50 species of fishes of all kinds, large and small, as recorded from the lake. Of these fully one-half are good, and the majority excellent food fishes, but some of them are now very rare.

In 1903, according to Cobb ('05) the commercial fishes of New York in this lake comprised only 9 kinds, of which the total catch amounted to 142,275 pounds valued at $10,245.00. Pickerel, bullheads and other catfish, yellow perch and smelt amounted to about 90 per cent of the catch. The apparatus employed in the fishery comprised hand-lines, set-lines, tip-ups, and spears. Only bullheads and catfish were reported as taken with set-lines; tip-ups took these same species besides yellow perch, pickerel and pikeperch. Only eels were taken with spears. On the Vermont side different methods prevailed. Lines and gill nets in addition to the apparatus used in New York were operated. Thirteen kinds of fish were reported, the great bulk of which were taken in seines, amounting to 490,552 pounds, valued at $33,179. No muskellunge or blackbass were reported, but besides those recorded for New York were sturgeon, suckers, sunfish, whitefish and lake herring. The total yield amounted to 528,682 pounds, valued at $37,669, of which pikeperch represented over 38 per cent. Smelts were taken on hand-lines only.

The total yield for Lake Champlain, exclusive of Canada, for which the figures are unknown, amounted to 670,957 pounds, valued at $47,914.

All of the kinds not ordinarily taken on hook and line apparatus, were caught in Vermont, comprising whitefish, lake herring, sturgeon and suckers, amounting to 119,686 pounds, valued at $7,737.00. Of these the suckers represented nearly 23 per cent.

Since 1903, commercial fishing on the interior waters of New York and in Vermont has been considerably reduced and restricted. Seines are no longer used in some waters where they were formerly permitted. Some years ago Vermont ceased to allow the use of seines in Lake Champlain, and in justification of that restriction reports for 1916 as follows: "The results of fishing for pikeperch on Lake Champlain have been very satisfactory; not only the anglers who fish for sport are rejoicing at the improved conditions, but there has sprung up a legitimate fishing industry in angling for pikeperch and other lake fish for the market, some of these commercial anglers making a very good living in a very congenial employment. The improved angling conditions on the lake have created a demand for guides or boatmen."

"Most of the fish caught by market fishermen are shipped to New York, and it is often impossible for individuals to buy fish in small quantities for home consumption.

"The sentiment in favor of seining for pikeperch in the spring of the year has practically disappeared; more money can be earned by angling and it is available to all inhabitants of the state, while the wholesale capture of fish by the operation of seines is limited to a comparatively few people." (Titcomb, '16, Pt. 2, pp. 5–6.)

Again, the same report (Pt. 1, pp. 78–79) says: "Under Section 65, which authorizes the Commissioner to remove, permit or cause to be removed from public or private waters, fish which hinder or prevent the propagation of game fish or food fish, a large number of permits have been issued for the taking of suckers or mullets, not only in trout waters but in tributaries of Lake Champlain and other lakes where these species are not easily obtainable except during the spawning season in the spring of the year and not very desirable as food after warm weather."

On another page of this report (Pt. 1, p. 80) the following paragraphs appear:

"Permit to remove ciscoes [lake herring] from Lake St. Catherine were issued to fifteen persons. These permits were effective from November 20th to December 20th only [spawning season?]. Nets over three hundred feet in length were prohibited, and all fishing was done under supervision of a warden. The holders of these permits were either residents of Vermont or taxpayers on improved real estate in Vermont appraised at not less than $1,000.00.

"It is the policy of the Commissioner to issue these permits on the basis that the fishery resources of the State should be made as productive as possible and that if the experiment of issuing permits in these waters proves successful, the same policy may be adopted in other waters such as Lake Bomoseen in Rutland County and Seymour Lake in Orleans County. The main point to bear in mind is the protection of the more important species which are so important to the public in general."

From the foregoing it is seen that permits for commercial fishing usually have been granted with one or the other of two objects in view. The stated object of one is that of *making the fishery resources as productive as possible.* The other object has been aimed at the destruction of species regarded as harmful in one way or another to the " more desirable fish," that is to say, game fish. Sometimes the two objects have been combined, or the first has been subordinated to the game fish interests.

Now just what successful outcome of the " experiment " of cisco netting in Lake St. Catherine was anticipated, is not stated. Judging from analogy, the month of open season for the netting was during the spawning time of these fish. If such was the case and the object was the destruction of the cisco the procedure would give full promise of success.

It appears that the bulk of the 600,000 pounds of suckers taken in 1903 in Oneida Lake was captured during the spawning time and was permitted for both of the aforementioned objects. Just what harm, if any, the ciscoes were to other " more desirable species " in Lake St. Catherine is not apparent. The alleged harmfulness of the suckers is based upon certain known propensities of those fish. But the possible, if not to say the probable, beneficial part suckers play in the natural economy of the waters has received no consideration.

As has been previously indicated, the destruction of these fish may defeat the intended purpose of their destruction. Even though a reduction of their numbers may be desirable in an effort to readjust a balance that has been disturbed by a reduction of the game fish to which the alleged harmful habits of the suckers or other fish pertain, their relation to other perhaps even more harmful forms should be taken into consideration. For instance, the bowfin which occurs in both Oneida Lake and Lake Champlain may be even more destructive to certain game fish of those lakes than are the suckers, and the relation of the suckers to the bowfin may be such that the destruction of the suckers would intensify the harmful effects of the bowfin upon the game fish. This is purely hypothetical, however, for these specific relationships are not as yet established as facts. But even this possibility indicates the necessity of ascertaining every such fact concerning the fishes in any body of water before intelligent regulation of fisheries can be established, and rational procedures replace " experiment." It is possible that some other method of fishing at some other season of the year would produce the desired results of productiveness of the fishery resources, with sufficient but not undue reduction of any species.

The game fish situation in Oneida Lake appears not to have been improved although the sucker supply has been greatly diminished. What is wrong can only be conjectured. A step, if not to say a stride, in the direction of a solution of the problem has already been taken in the surveys to which previous reference has been made. What is now needed is continuation and amplification of the work already begun.

In the case of Lake Champlain neither game fish nor non-game fish are maintained to the economic maximum. In fact, some valuable species have been reduced almost to extinction, notwithstanding the fact that net-fishing in New York State has not been permitted for a long time and has been prohibited in Vermont for a number of years. Undoubtedly there are other factors than fishing operative in the decrease of food and game fishes in that lake. The nature of some of them is apparent if not quite evident, but there are unknown factors which must be ascertained before the problem of how to rehabilitate the lake or maintain the present stock in it can be solved. Lake Champlain is a large body of water which, if properly regulated, might afford valuable fisheries for all time. The States of New York and Vermont control the greatest extent of water, although a comparatively small but important portion comes under the jurisdiction of Canada. It would seem that the lake affords such important fisheries possibilities that it demands international and interstate cooperation in an investigation, the results of which would provide basic knowledge for the joint establishment of adequate fish cultural procedures and rational effort directed toward the development and regulation of these fisheries.

RETROSPECT AND REFLECTIONS

The foregoing discussions embody only a small part of the evidence which shows that, from early times to the present, most of the efforts to restore and maintain the fisheries have been injudicious. But it would seem that enough evidence in that direction has been presented to afford food for thought, and to indicate that revised, if not to say reformed, restorative and constructive measures must be adopted, if the fishery resources are to be preserved for future generations. This discussion has pertained mainly to the "game fishes," for the reason that the State has given its principal attention to those species, but enough has been said to show that it is impossible to disregard the other kinds of fish. The game fish form only a part of the whole, and regulations pertaining to game fish involve correlated regulations pertaining to all other associated fishes. Again, regulations pertaining to the whole, or to the perpetuity of any important part of the whole, can be constructively effective only when based upon exact knowledge. Exact knowledge is available only through intensive and prolonged study of all conditions pertaining to the objects of regulation.

It has been repeatedly asserted that such studies have been too scattered, too fragmentary, or too incomplete to afford the necessary foundation for rational procedures and regulations. There is primary need for a sustained, constructive policy toward investigations of the fishery resources. Perhaps one reason for the unsatisfactory condition is that the fishery interests are so diverse, as some of them are located on international boundaries, some on State boundaries, and still others involve both international and State interests. That is to say, one body of water may border on several states and Canada, as for instance Lake Champlain. As a rule only the smaller bodies of water are wholly within the borders of any one state.

It is true that there have been international fisheries commissions, and interstate conferences concerning regulation of boundary waters, but none concerning the possibility of establishing a foundation for intelligent regulation through biological and ecological investigations. Now and then the Federal government of the United States and the Dominion government of Canada have made independent sporadic observations, of one kind or another, and it may be said to Canada's credit, that she has been more persistent and consistent in that direction than has the United States government. Occasionally, too, a state, either in connection with the Federal government or alone, has made a beginning in the desired direction, but while the investigations pertaining to certain problems never have been concluded, they never have been even approximately completed.

As concerns the State of New York, the foregoing brief review of the "surveys" and "investigations" of its streams and lakes, reveals that they have been few in number, of limited geographical extent, and likewise limited in results immediately applicable to policies or procedures of fish conservation. The reason is that although special subjects, in one or another body of water have been quite thoroughly studied, others have received little or no attention, or else studies of one kind have been made in one body of water and those of another kind have been made in another, but in most instances the correlation of the results has not been possible. In fact no biological survey of any body of water that has been made in the State can be said to be complete in itself. Each may afford data that in a general way may be correlated with those of another, but few, if any, positive conclusions of definite practical application to any one body of water can be drawn from disconnected and temporary studies. Therefore, a definite, permanent and sustained policy of investigation is the price requisite for success.

It would be a serious oversight to conclude this discussion of the fish cultural investigations in this State without pointing out the remarkable situation with regard to the Hudson River. Here is our largest river, discovered over 300 years ago, and a stream without question of considerable capacity for producing inland fish in its upper portion. Aside from the intensive studies of the pollution of its lower section, what is known of the detailed biological conditions and of the fishery problems of this stream? In spite of the numerous educational and scientific institutions scattered along its course, and the great museums within sight of it, this stream remains to this day, so far as the fundamentals of its fishery needs are concerned, a veritable wilderness, as uncharted and unexplored as central Africa or Siberia. This is indeed a strange situation.

When the people of this State awaken to the anomaly of the situation and begin their serious study of this stream, they will have to turn for guidance to the Central West, where the Illinois River has now been seriously studied for a generation from the standpoint of its biology and its fisheries by Forbes and his associates, Kofoid, Richardson, and others. The results of their investigations form the most extensive body of data on the biology of any stream in America and indicate what should be done for the Hudson.

(Cf. Forbes, '10, '11, '11a, '13; Forbes and Richardson, '13 and '19; and Richardson, '21.)

However, under present conditions it is not practicable for any states, or any institutions, to make an intensive biological and physiographical survey of every body of water, large or small, within a state, or in an extensive territory, within a limited time, or even in a long time, as it would require a larger force of specialists than is available, even if the necessary funds were available.

Outside of the United States Bureau of Fisheries, and to a considerable extent within it, scientists connected with institutions of learning have been practically the main dependence of the states for investigations of waters and fisheries. The scientific personnel of the United States Bureau of Fisheries has been and still is too limited in number, and the calls upon it too many, to permit of their general availability for investigations of sufficient duration to positively solve comprehensive problems.

College professors have rendered excellent service during summer vacations in collecting facts pertaining to lake and stream conditions. In fact the bulk of such knowledge, in recent years, has been obtained by them, and often without pecuniary compensation. The summer months, however, do not afford all the facts necessary for securing positive results upon which to base recommendations concerning fish and fisheries policies and procedures. Besides, their time for adequately analyzing the facts in hand is limited because of their college duties. It is such considerations which led Baker to suggest ('16, p. 316) permanent biological investigations on Oneida Lake. So perhaps in some cases in order to satisfy the demands for results by those who do not understand that a brief investigation cannot fill the requirements, the investigators may make hasty recommendations, if they venture to make any at all. Too often such recommendations, although based upon admittedly incomplete studies, are often accepted as final by officials and the public, when they are only preliminary and provisional. To repeat, partial investigations are made here and there every year; sometimes of one species, one problem, or one environment at a time, but they are incomplete and are never completed. Possibly no one makes further study of the subjects, either singly or in combination, for many years. It is well to emphasize here that there always will be problems, and investigations should never cease, because new situations and conditions are constantly arising. The investigations must be as continuous as the fishing.

Yet it is true, that every investigation, however incomplete it may be, adds to the stock of accumulated facts, inferences and principles; but if recommendations are based upon conjectures, the tendency is for subsequent fish cultural procedure to be as uncertain as before.

In the case of the streams of Oneida County, of which it is stated there are approximately 2,000 miles, all were investigated during the one season. Such hurried and partial examinations are manifestly inadequate, but the value of the work is considerable, if it does not stop there. Usually it does stop with the preliminary observations, for often those in control of the funds can see no advantage to be gained by further work along such lines, especially if the report upon the "survey" injudiciously claims that it was "thorough enough for all practical purposes."

At a convention of the National Association of Fish Commissioners, John W. Titcomb, then State Fish Culturist of New York, said (Titcomb, '17): "It becomes apparent that in order to obtain the best results, a permanent policy must be established with regard to each stream, pond or lake which is to receive attention. In other words, the Commissioners of the different states should have a survey made of all the waters under their jurisdiction which are to receive any attention in the way of restocking. The results of the survey should be published in such a way that the successors of those who established the policy may have something to guide them in their efforts with reference to the same waters."

To this recommendation it may be added that to that end the Conservation Commission, or State Fish and Game Department, of each State should cooperate with a permanent and financially well-supported department or departments for the investigation of wild life, and one upon which it may depend. These administrative departments of the State governments have not, in the past, been able to furnish the facilities, in laboratories, libraries, or experiment stations, or the maintenance of the scientific staff, or an atmosphere favorable to prolonged scientific study of these wild life problems. It is probably only at special research stations, and at colleges and universities, that we can expect the most of such work to be conducted, where there is an atmosphere favorable for research and education, rather than that of administration. In New York State, the Roosevelt Wild Life Forest Experiment Station has been authorized by the State to perform just such functions, and it only needs adequate support to execute the kind of investigations that have been outlined in this paper for public waters, and such as it has already been conducting for several years in various parts of the State in the forest waters.

As concerns game fishes the purpose of such investigations should be to make as exhaustive a study of the lakes and streams as possible, which may be taken as representative of the various conditions generally obtaining in different sections of the State, and as heretofore, making use of such outside scientific help as may be available. By this means a definite policy could be more quickly and economically formulated and carried out than by present methods, of which the practical results lie far in the future. In fact they may lie so far in the future, that there will be no opportunity for practical application, in that the game fish will have joined the passenger pigeon in the "happy hunting grounds." This may appear like the fears of a calamitist, but one does not have to go far, and open his eyes very wide, to see what the present conditions are. If he considers them in relation to the expenditure of effort and money during the past 40 or 50 years, and if he has any interests beyond those of his own immediate selfish ends, he will realize that if the downward trend continues at the same rate for even a few years longer, there is just cause for real alarm.

It cannot be expected that all planting shall cease until thorough investigations are made. But there should be a certain amount of judgment exercised and that judgment should be based upon examination of the waters to be stocked.

And for the sake of emphasis, it again may be said, in the words of Evermann and Clark ('20): "No stream or lake should be stocked with fish until it has been carefully studied by a competent biologist and found to possess the conditions or factors of favorable environment for the fish which it is proposed to introduce. Fish culturists should adopt this principle and adhere to it as an invariable policy. The rule of thumb, cut-and-try method so uniformly followed has brought no credit to fish culture in America."

It should be unnecessary to enlarge upon the last two paragraphs. The moral is: Know your lakes and streams; likewise know your fish; correlate the two and act accordingly. You cannot know the lake or stream without a thorough biological or ecological investigation; you cannot know the fish without a thorough study of its life history and habits, and you can no longer have fish without paying the price, in intelligence and funds, necessary to produce them.

SUMMARY AND CONCLUSIONS

1. The original fish resources of America and of New York State were not surpassed in variety or in kinds of food and game fish by any other continent or any State in the Union.

2. The primeval fish resources of America were bountiful; but these resources, like those of the game and forests, have been ruthlessly wasted and destroyed.

3. With the decline of this resource there was a period of reckless and random efforts to introduce foreign species, which were planted broadcast through the country in all sorts of conditions, to the detriment of all fisheries.

4. The proper evaluation of the native resources is just beginning to be appreciated, but no adequate Federal or State policies have been deliberately formulated and practiced. There is only a slight awakening to the need of such a constructive program.

5. The formulation of constructive policies involves detailed, comprehensive, scientific studies of this resource, such as have already been most successfully conducted at research or educational institutions, rather than in connection with administrative departments of the various states.

6. Because of the instability of political management of the fishery resources the conservation of fishes should be as free as possible from political interference.

7. Too often fish hatcheries, as commonly conducted, have depleted the local stock of breeding fishes in their immediate vicinity, in order to stock other more remote waters. As the customary planting methods are so frequently unsatisfactory this waste has tended to spread depletion *radially* from the hatcheries.

8. To maintain the breeding stock of fishes for the hatcheries and even to insure the existence of some species, it has already become imperative that *fish preserves,* like game sanctuaries, should be established at critical localities, as both State and Federal preserves.

9. Similarly, to conserve the breeding stock, the investigation of *post-hatchery problems of fish culture* must be enlarged and perfected, and be based on adequate field surveys.

10. To supplement proper planting a campaign of education among all organizations and individuals who plant fish will be necessary to prevent waste, or the gains made by improved methods will be diminished.

11. The problems demanding investigation are too complex and difficult to expect immediate solution all along the line. A sufficient technical staff should be available to permit part of it to be devoted to the continuous survey of the waters, and to problems involving more immediate attention, and the remainder of the staff to be devoted to other important problems, which require much more time for solution.

12. The public should be made fully aware of the magnitude of the difficulties involved in an investigative program for fish, so that they will come to realize that to maintain this resource there must be a continuous, permanent program, one which can never be *completed* so long as the resource lasts, and so long as conditions change which influence the fish. Investigations must be as constant as taxes.

13. From the standpoint of the general public, the *public* waters seem destined to soon become the last, and almost only accessible angling and fishing waters. The most accessible of these will be in the State forests and State parks, on the non-agricultural lands of the State. For this reason the systems or policies of management will be, in the main, those governing forest lands, and they should be so organized that there will be harmonious, consistent management for forests, fish and game, such as can best be established under a unified conservation commission.

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CURRENT STATION NOTES

CONSERVATION VERSUS EXTERMINATION.

The present number of the *Bulletin* is devoted exclusively to a discussion of the broad principles of the conservation of fish in our inland public waters. This subject has not been similarly treated previously, and Dr. W. C. Kendall's long experience in these matters, while an official in the U. S. Bureau of Fisheries, gives his conclusions and opinions great weight. It is evident that in these matters we have been drifting, and have been whirling about in eddies instead of advancing in the main stream. As a result of this method a vast amount of human effort, labor and funds has been wasted. Many times have the effort and funds been lost that, under proper management, would have put the whole problem of our inland waters upon a thoroughly sound basis. The need of a broad perspective, such as can only be secured by scanning the whole field, has not been sufficiently realized. Even to many of the leaders in conservation, the views here expressed by Dr. Kendall will come as a great surprise and they should stimulate serious thought in the minds of many people.

With increasing population, and a more intensive use and abuse of our inland waters, the situation becomes constantly more complex and serious. The drainage of lakes, ponds and swamps, the contamination of inland waters by sewage and industrial refuse, the damming and otherwise obstructing of streams, have the same general unfavorable tendency; and finally by overfishing and defective and inefficient fish culture, the same tendencies are emphasized. All these conditions seriously interfere with maintaining the fisheries, and this has furnished the basis for concern. Of course, some of these changes are inevitable, with the industrialization of the country; but that is often only the excuse, and not the cause, for some of the gross blunders that have been made. We are now reaching the point where the public has begun to see the seriousness of the situation, and is beginning to take measures to ward off the threatening consequences. Constructive measures will have to be developed by increasing scientific investigations of fishery problems, in order to have a substantial basis of fact for practical conservation measures. Furthermore, anglers, fishermen, sportsmen and conservationists of all kinds, must be educated to the realization that conservation must be put into the hands of trained men, and must be freed, as much as is humanly possible, from political interference of all kinds. There seems to be a growing belief today that the greatest and most sinister influence affecting wild life, if any one can be singled out, is "politics." The most hopeful remedy for dealing with such a problem is by giving the public reliable information, rather than the usual too abundant "propaganda," and by elevating the standard of practical ideals in both conservation and in politics.

COOPERATION WITH UNITED STATES BUREAU OF FISHERIES

The Roosevelt Station has consistently endeavored to cooperate with other agencies engaged in wild life research. This has been the continuation of a policy adopted by the College in 1915 when it began the investigation of the fishery problems of Oneida Lake. In 1917 a beginning was made, with the United States Bureau of Fisheries, on a study of the fish parasites in that lake. This cooperation was made possible, to an important degree, by the broad-minded policy and active interest of Dr. Robert E. Coker, at that time in charge of the Division of Scientific Inquiry of the Bureau, and now at the University of North Carolina at Chapel Hill. It resulted in Dr. H. S. Pratt's paper, on "*Parasites of Fresh-Water Fishes*" (U. S. Bur. Fisheries Econ. Cir. No. 42, pp. 1-8, 1919), and his "*Preliminary Report on the Parasitic Worms of Oneida Lake, New York,*" and Dr. H. J. Van Cleave's "*Acanthocephala from the Fishes of Oneida Lake, New York,*" both published in a preceding number of this *Bulletin*. While the Roosevelt Station was conducting investigations in the Palisades Interstate Park, on the Hudson River, in cooperation with its Commissioners, the Bureau of Fisheries again cooperated and the resultant publications were two papers by Dr. J. Percy Moore, one on the "*Use of Fishes for Control of Mosquitoes in Northern Fresh Waters of the United States*" (U. S. Bur. Fisheries, Ann. Report for 1922, Appendix, pp. 1-60. Doc. No. 923, 1922), and the other on "*The Control of Blood-sucking Leeches, with an Account of the Leeches of Palisades Interstate Park,*" also published in an earlier number of this *Bulletin*. Still another result of this work has already appeared as "*A Preliminary Report on a Fish Cultural Policy for the Palisades Interstate Park,*" by Charles C. Adams, T. L. Hankinson and W. C. Kendall (Trans. Amer. Fisheries Soc., Vol. 48, pp. 193-204, 1919). In this particular study, Dr. W. C. Kendall represented the Bureau of Fisheries. It is anticipated that similar cooperation will be continued in the future.

A NOTABLE GIFT TO THE STATION

Early in June, 1923, the Roosevelt Station received a valuable gift in the form of an exhibit, showing in fourteen stages the preparation of Hudson seal or seal-dyed muskrat, from the raw skin as received from the trappers, to the fully dyed fur. This exhibit is enclosed in a polished mahogany case twenty feet long, with plate glass front, and with electrical illumination. The whole exhibit is beautifully executed, and is both very attractive and instructive. This gift was made by A. Hollander & Son, of Newark, New Jersey, the leading dyers of this fur, and through the friendly services of Mr. Max Herskovitz, of Alfred Herskovitz & Son, New York City. The gift is greatly appreciated because, from the inception of the Roosevelt Station, plans for the study of fur bearing animals have been included in its program, and such an exhibit is a very valuable addition to its equipment. New York City is today the leading center of the fur industry in the world, but unfortunately we have comparatively few adequate statistics on this subject. A recent rough estimate of the annual wholesale value of the manufactured furs in the United States gives it as approximately $200,000,000.00 to $250,000,000.00, and the value of materials entering into their manufacture is practically one-half of that amount. These figures show the great economic importance of this industry. The muskrat is considered our most important fur bearing animal. In the fur industry the status of the muskrat is at any time considered a fair index to the condition of the business, just as pig-iron is taken as a barometer of the steel industry. An estimate was made in 1920 showing that in New York City the annual business involved in handling muskrat fur is in excess of $200,000,000.00. During the year 1922 over 9,000,000 muskrat skins alone were dressed in that vicinity and of these over 8,000,000 were dyed there.

THE DECLINE OF FUR BEARING ANIMALS

Speaking broadly, many of the points made by Dr. Kendall in discussing fish, apply also to game and fur bearing animals. The same general principles which serve as a basis for the remedies suggested apply to wild life as a whole.

With the settlement of the country there has been, in general, a great decline in fur bearing animals, and at the same time there has been a greatly increased demand for furs. There have been many causes for this decline, including not only the trapping of furs and hunting, but as well the cultivation of the land, drainage, destruction of forests, rodent poisoning campaigns, and the destruction of predatory stock-killing animals and "game vermin." All have taken their toll until the future of this resource has become the cause of serious concern, particularly among the naturalists, and more recently among the broader minded of the men in the fur industry who are looking forward toward the permanence of their own industry, and who realize that a sustained annual yield of raw fur is the very foundation of their business. The situation in the industry reminds one of the old saying that: "We never miss the water 'til the well runs dry." Naturalists have made the mistake of not warning the public more fully of the true drift of events, and the fur industry has not in the past been accustomed to look to naturalists for help in solving their scientific problems. The situation has now become serious and the leaders in the industry are beginning to realize that scientific study of the life history, habits, and methods of propagation of fur bearing animals is not incidental but essential to the present and future welfare and the very existence of the business. One of the immediate problems now gaining recognition is that it is becoming more important to spend hundreds of thousands of dollars upon scientific studies and educational campaigns for increasing *fur production* than to spend a similar amount on advertising or other activities which are concerned solely with consumption. A new situation has arisen and it must be solved by new methods.

INCREASING FUR BEARING ANIMALS IN NEW YORK STATE

During the summer of 1923, Dr. Charles E. Johnson, Roosevelt Fur Naturalist, who made the Adirondack beaver study for the Station, devoted his time to field studies for the determination of the condition of the muskrat in Western New York. Secondarily, attention was given to the skunk and the raccoon. He began a comprehensive study of these animals, with a view toward increasing our knowledge of their natural history and breeding habits, and to methods of increasing their numbers on a large scale. The herbivorous habits of the muskrat and its rapid rate of reproduction indicate it to be the sort of animal adapted to large scale production, and a means of utilizing non-agricultural swamp lands, otherwise relatively non-productive, making them economically comparable to intensively cultivated farm lands.

THE ROOSEVELT WILD LIFE MEMORIAL

As a State Memorial

The State of New York is the trustee of this wild life Memorial to Theodore Roosevelt. The New York State College of Forestry at Syracuse is a State institution supported solely by State funds, and the Roosevelt Wild Life Forest Experiment Station is a part of this institution. The Trustees are State officials. A legislative mandate instructed them as follows:

"To establish and conduct an experimental station to be known as 'Roosevelt Wild Life Forest Experiment Station,' in which there shall be maintained records of the results of the experiments and investigations made and research work accomplished; also a library of works, publications, papers and data having to do with wild life, together with means for practical illustration and demonstration, which library shall, at all reasonable hours, be open to the public." [Laws of New York, chapter 536. Became a law May 10, 1919.]

As a General Memorial

While this Memorial Station was founded by New York State, its functions are not limited solely to the State. The Trustees are further authorized to cooperate with other agencies, so that the work is by no means limited to the boundaries of the State or by State funds. Provision for this has been made by the law as follows:

"To enter into any contract necessary or appropriate for carrying out any of the purposes or objects of the College, including such as shall involve cooperation with any person, corporation or association or any department of the government of the State of New York or of the United States in laboratory, experimental, investigative or research work, and the acceptance from such person, corporation, association, or department of the State or Federal government of gifts or contributions of money, expert service, labor, materials, apparatus, appliances or other property in connection therewith." [Laws of New York, chapter 42. Became a law March 7, 1918.]

By these laws the Empire State has made provision to conduct forest wild life research upon a comprehensive basis, and on a plan as broad as that approved by Theodore Roosevelt himself.

Form of Bequest to the Roosevelt Wild Life Memorial

I hereby give and bequeath to the Roosevelt Wild Life Forest Experiment Station of The New York State College of Forestry at Syracuse, for wild life research, library, and for publication, the sum of ...., or the following books, lands, etc.

Syracuse Univ. Bull. FEBRUARY, 1925 Vol. 24, No. 23

Roosevelt Wild Life Bulletin

VOLUME 2, NUMBER 4

OF THE

Roosevelt Wild Life Forest Experiment Station

OF

THE NEW YORK STATE COLLEGE OF FORESTRY

AT SYRACUSE UNIVERSITY

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The serial publications of the Roosevelt Wild Life Forest Experiment Station consist of the following:

1. **Roosevelt Wild Life Bulletin.**
2. **Roosevelt Wild Life Annals.**

The *Bulletin* is intended to include papers of general and popular interest on the various phases of forest wild life, and the *Annals* those of a more technical nature or having a less widespread interest.

These publications are edited in cooperation with the College Committee on Publications.

The editions of these publications are limited and do not permit of general free distribution. Exchanges are invited. The subscription price of the *Bulletin* is $4.00 per volume of four numbers, or $1.00 per single number. The price of the *Annals* is $5.00 per volume of four numbers, or $1.25 per single number. All communications concerning publications should be addressed to

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*Including only those who have made field investigations and whose reports are now in preparation.
**Resigned as Station Ichthyologist October 1, 1921.

THE RELATION OF FORESTS AND FORESTRY TO HUMAN WELFARE

"Forests are more than trees. They are rather land areas on which are associated various forms of plant and animal life. The forester must deal with all. Wild life is as essentially and legitimately a part of his care as are water, wood and forage. Forest administration should be planned with a view to realizing all possible benefits from the land areas handled. It should take account of their indirect value for recreation and health as well as their value for the production of salable material; and of their value for the production of meat, hides and furs of all kinds as well as for the production of wood and the protection of water supplies.

"Unquestionably the working out of a program of wild life protection which will give due weight to all the interests affected is a delicate task. It is impossible to harmonize the difference between the economic, the aesthetic, the sporting and the commercial viewpoint. Nevertheless, the practical difficulties are not so great as they appear on the surface."

Henry S. Graves,
Former Chief Forester, U. S. Forest Service.
Recreation, Vol. 52, p. 236, 1915.

RESEARCH ON WILD LIFE

"The discovery of new species and races based upon the study of preserved specimens of game animals, has already progressed very far; but the more attractive field which includes the habits of the game remains yet to a great extent unexplored. This field is peculiarly open for investigation to big-game hunters, and to all other men who go far afield and obtain first-hand knowledge of the conditions under which the game animals live. The closet naturalist, with his technical knowledge of the structure of animals, can be trusted to perform the work of classification to a mathematical degree of precision; but we cannot obtain from him a trustworthy account of the behavior of animals in their natural environment, or learn from him the value to the animals of the various structures or characteristics which he has shown them to possess. Much knowledge regarding the habits of game is acquired by the successful sportsman. Yet it is often infinitesimal in quantity compared to what may be acquired if the outdoors observer will direct his investigations along the broad lines covering the life history of the species with which he comes in contact. To carry out such investigations successfully it would be necessary to spend many hours and days, perhaps even weeks and months, observing certain individuals or family groups of game. This is quite beyond the limits of time allotted the average sportsman. Nevertheless much can be learned by the collected evidence from many fragmentary observations providing only these are accurate. A great mass of accurate fragmentary observations will often spell far more progress in investigations of this kind than the observations of a few trained individuals over an extended period of time."

Theodore Roosevelt and Edmund Heller.
Life Histories of African Game Animals,
Vol. 1, pp. vii-viii, 1914.

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Drawn by Edmund J. Sawyer.

PLATE 25. A BLACK BEAR FAMILY IN THE YELLOWSTONE PARK.

THE RELATION OF WILD LIFE TO THE PUBLIC IN NATIONAL AND STATE PARKS*

By Dr. Charles C. Adams,

Director, Roosevelt Wild Life Forest Experiment Station, Syracuse, New York.

CONTENTS

INTRODUCTION AND ASSUMPTIONS

The value of wild life in our State and National Parks depends directly upon what we are willing to do to make proper use of it. If wild life is neglected or ignored little benefit will be derived from it, and if, on the other hand, it is carefully cared for and the public is intelligently encouraged to appreciate it, much benefit will be derived from it. As in the case of most things it is of the greatest importance to realize that we can get from wild life only what we are willing to put into it. If you know a park where little is derived from wild life you know one at once in which little has been done for it.

A second fact of basic importance is that the welfare of wild life in the parks will depend fundamentally upon the welfare of the parks as a whole. Their interests are mutual and interdependent, and we must not expect wild life to be cared for and appreciated if the parks as a whole are not. Our main practical point is to strive to see that the wild life of our parks receives all consideration that

*A revision, with additions, of Adams, '23.

it fairly merits, and in accomplishing this the best interests of the parks will be promoted. I have no plea for the special consideration of wild life.

Generally speaking I fear that too many of our park administrators think of wild life mainly when it *conflicts* with their visiting public, that is, when an animal disturbs or injures the park visitors. In the Palisades Interstate Park poisonous snakes, leeches, mosquitoes and "water bloom" are examples of this sort of unpleasant relation between the public and the native organic population of the park. But this is only one aspect of the animal problem. In addition to this protective phase there is as well an even more important one which concerns the active interest in parks caused by the presence of wild life. We have in the United States thousands of small and large local and national organizations devoted to and centering about some branch of natural history. There are bird clubs, flower clubs and entomological societies of great variety. Then there are literally hundreds of sportmen's and outdoor organizations of all kinds, a large number of which take a healthy and sane interest in wild animals. In the aggregate these people make a considerable assemblage who can be depended upon, under proper leadership, to take much interest in wild nature in these parks and work for its welfare. So far as known to me no systematic effort has been made to interest and enlist the support of *all* such organizations. In England this class of people has for a long time been one of the main supporters of the large public parks. Thus Buxton ('84, pp. vi-vii) writes:

"I find that the most intelligent interest is taken in our woodlands by those who there pursue their studies in one or other of the branches of Natural History. Many of them are of humble station; but as members of societies, which are very numerous in London, of botanists, ornithologists, fungologists and microscopists, they are enthusiastic searchers into nature. I have therefore added some chapters on the different forms of life which they may expect to find in the course of their rambles."

While I shall refer mainly to wild life I wish it clearly understood that this implies also a *proper living environment for it,* in order to be assured of its best utilization by the public. This involves natural living conditions when living free, and suitable conditions when confined.

Although speaking primarily of animals I believe that the general principles discussed apply to many other features of nature, including the geography, geology, the plants and the scenery:

phases of nature to which, except the scenery, we have not yet given adequate attention.

It will help clear up the point of view from which I have discussed the park problem, to state definitely the assumptions upon which I have based my remarks. Probably some will not agree with me on certain of these points. I hope that those who do not accept them will see the need of a thorough discussion of these points, and that later they will assist in elucidating them. For brevity I will state them without discussion as follows:

1. The publicly owned National and State Parks are devoted solely to the public welfare. The wild life in them is public property and should harmonize with all other uses of the parks.

2. This social ideal includes the recreational, educational, scientific and aesthetic interests, and should exclude all commercialization of the parks.

3. The main criterion of proper use is that which is harmonious with permanent or sustained use—to pass on to future generations, unimpaired, the natural resources of the parks. The present generation has no honest claim to more than a fair share.

4. The ideal and the practical must be combined in order to harmonize with the preceding.

5. These parks, to be maintained upon a permanent basis, must remain primarily a wilderness,—at least our National Parks, and most State Parks should strive for at least a part of their area to be reserved for that purpose.

6. All the wild parks should exclude from within their boundaries all plants and animals not native to the region. These areas cannot be passed on to future generations unimpaired, if they are periodically stocked with exotics.

RELATION OF WILD LIFE TO THE PUBLIC

The most important relation of animals to the public is their *attractiveness* to park visitors. The silent grass-lands and forests without birds and other animals lose much of their charm to a host of people who will never become bird students. The presence of beaver dams and lodges, and the prospect of seeing these animals at work, are powerful attractions in the Adirondacks and in the Yellowstone. The mere presence of bears (Plate 25), buffalo, elk, deer or moose has an appeal that no intelligent person, at all acquainted with the public in the presence of these animals, can doubt (cf. Grinnell and Storer, '16). And these attractions lose none of their charm even in the midst of the most wonderful scenery; in fact, as a rule, the scenery only adds to their charm. I believe that this relation is now generally recognized among all who have given thought to this subject. At present the practical problem is how to devise means of bringing together wild life and the public under the most favorable conditions. The following are the most prominent methods which have been suggested and used, but the truth is that none of them has been thoroughly tested out in more than a few features.

Guide Books and Other Publications.—Our National Parks have been particularly fortunate in the character of their chief champions who have given us a series of books of remarkable value. The writings of John Muir are a permanent contribution to our literature, and will speak of the value of wild nature through the ages to many coming generations. The published guide book, as a method of presenting nature and wild life to park visitors, is a means deserving of much study and worthy of generous support. In spite of this being a well-known method its application to our parks has not made much progress; only a few experiments along this line have been tried out, and generally these have been limited to catalogues and lists with a few notes, descriptions, and observations on animal habits. This method has long been out of date with modern teachers of outdoor biology in our best colleges, where plant and animal ecology is taught. These lists of animals have their place and a certain value, but they should be held in the background, as it is now clearly recognized that this is not the most successful method.

It is a great mistake to assume that there is only one kind of popular guide. There are many avenues of approach which have not yet been explored and experimentally studied. These include the aesthetic approach, that of the amateur naturalist, the student of nature-study, that of teachers and leaders of youth of all kinds, and finally that of the very superficial park visitor, who must also be approached from various angles. Not only should the literary style vary with the method, but type, half-tones, maps and colored plates must all be enlisted in a program to entertain and enlighten the visiting public.

One of the most attractive guides published on an American park is that by Safford: *Natural History of Paradise Key and the Near-by Everglades of Florida* ('19). The illustrations, half-tones, maps and colored plates of this guide are a model in many respects. Another recent and very attractive guide book assembled by Hall ('21) for the Yosemite National Park, is evidently modeled after *Nature and Science on the Pacific Coast* (P. Elder and Co., San Francisco, 1915) which set a new standard. The first of these park guide books, by Chittenden, on the Yellowstone, has much real merit even today. In this connection attention should be called to a recent book by Downing ('22) on the Chicago region. Although not written primarily for the Cook County Forest, which is in reality a large forest park, it serves as a nature guide manual for that region.

It has too often been assumed that our only need is for popular literature on the wild life of our parks. But there is also an urgent need of detailed information of a scientific character, as well as of a technical nature concerning the administrative problems of parks. We urgently need a great variety of publications, including the popular, scientific and technical; and some persons must continuously stress the need of the less popular publications, because the success of our parks cannot be assured without a basal up-to-date knowledge of the facts of nature in them.

We continually meet with critics of the technical and scientific publications, and often similar criticisms of the popular. The critic of the non-popular literature does not realize that most of this has been written by those who on their own time and expense have made these studies and naturally feel free to choose how they shall present their results. Those who are eager for the popular accounts can secure these also, without question, if they are willing to pay the necessary price. There are many naturalists who would gladly make the studies and prepare popular reports, provided the facilities were given them to do the work. An understanding and a reasonable expectation from each group would lead to better mutual understanding and appreciation. For my own part I feel that the public is really getting a generous supply of help compared with what they have put into such work. Too often we expect to harvest where we have not planted.

The New York State College of Forestry and its Roosevelt Wild Life Forest Experiment Station have definitely experimented with popular bulletins on birds for park and forest visitors. One has been prepared for the Palisades Interstate Park, a second for the Adirondack region—both by Silloway ('20a, '23)— and a third, by Saunders ('23), for the new Allegany State Park south of Buffalo. Another very attractive type of handbook on birds, arranged for use as one tours the Yellowstone National Park, is by M. P. Skinner ('25), formerly Park Naturalist there. This author has made a special study of the tourists' interests as well as of the birds themselves. His *Yellowstone Nature Book* ('24) also shows skillful treatment applied to the general natural history of the Park. We are deliberately experimenting, as I have said, with several methods of approach in these popular guides. Birds are particularly adapted for such experiments on account of the widespread popular interest in them. There is an active, strenuous type of person who gets his pleasure while on the way, in pursuit of the birds. The eye-minded and the ear-minded student, each makes best progress by a different approach. Then there is also the contemplative attitude, the aesthetic as well as that of the understanding, so beautifully blended in Muir. Of course there are those who feel that we should ignore such differences in persons, but that is dodging the problem instead of solving it. These tendencies are by no means limited to bird study, for they are of general application. The papers in this number of the *Bulletin* by Heller ('25) and Muttkowski ('25) are examples of similar popular accounts of fish and mammals in the Yellowstone. Nor does the plea for economy in publications hold, because it is one of the first obligations to adapt our park methods to a large public, and particularly to that kind of public which will best appreciate the parks.

Experiments are also needed on guide booklets to the natural history of trails. These booklets must be the result of outdoor study and should be made to fit special trails and localities. The whole technique of laying out these trails is a virgin field awaiting detailed investigation. A special knowledge of natural history, particularly of ecology, is one of the essentials for such work. The marking of the trail must be expanded to include an intelligent labeling of what can be seen along it. This work must not be overdone and thus disfigure the trails, but the labeling of noteworthy geologic and geographic features, plant colonies, striking individual trees, and the haunts of certain animals, will have a wonderful influence in stimulating a healthy and intelligent interest in outdoor nature. Wild life interests will fit into such a program beautifully, but as you will see, it will be useless to urge this for wild life alone, as these various outdoor interests are all bound up so closely that all will best progress together.

Lectures, Excursions and Nature Guides.—Oral leadership in the form of lectures, conducted field excursions, and guides, has already made a beginning in some of our parks. Lectures have easily led because speakers have been easier to secure than the various kinds of leaders needed for field parties and because larger numbers can be accommodated. By all means these lectures should be primarily limited to the particular park and to teaching appreciation of it. The conducting of field parties is difficult work, requires special training, both in subject-matter and method (Adams, '10, '21), and is I believe destined to become one of the most important methods of assisting the public. I believe that it is a great mistake to assume that the public can grasp only the simplest facts and relations, and that it is useless to attempt to give the larger conceptions. I do not think that this is true even of lectures, because with proper accessories, slides, maps and models, much can be done. Field excursions can often be planned to present the larger and more striking conceptions to wonderful advantage. Not enough is made of these larger ideas, so that often the public feels that to know the name of an animal, a plant, or a rock is all there is to science, and is wholly unaware of the existence of the larger ideas (cf. Adams, '10, pp. 119–121). I believe that adequate guide leaflets, guides on the trails, and properly placed trails, will do as much if not more for the intelligent appreciation of wild life and the parks than any single method (cf. Mills, '20).

Lecturing with pertinent slides, moving pictures and other appropriate equipment, can accomplish a great deal when large numbers of people are concerned; but it can never take the place of the field guide. The lecture is particularly suited to those spending very limited time in our parks; but those who camp, or who tour slowly either by auto or on foot, have in the main other ideas and needs. In the Palisades Interstate Park, Mr. P. M. Silloway conducted field excursions for bird study (1918) and Prof. T. L. Hankinson and I conducted similar excursions about the lakes and introduced groups of boys to the wonders of animal life in the waters. We all cooperated in laying out trails and marking them. The primary emphasis was placed upon aiding people to get outdoors, observing, thinking and enjoying themselves, because fundamentally it is supervised nature work first, followed by the self-directed kind, which leads to the best results in the long run. In the case of city visitors, who do not know the country, and do not know what to do in a strange place, they naturally gravitate back to and demand city diversions, but under skilled leaders much progress can be made toward getting them away from these deep-set habits (cf. Adams, '21).

In the Yosemite National Park, Dr. H. C. Bryant began field excursions and lectures, for both adults and children, in 1920, and these have been keenly appreciated (cf. *Twenty-sixth Biennial Report, California Fish and Game Commission*, pp. 80-82, 1921).

In this work Dr. L. H. Miller, by his wonderful reproduction of bird music and its interpretation to the public, has opened up a new world to the park visitor.

Museums, Libraries and Zoological Exhibits.—It is only the advanced administrators of our parks who have become fully alert to the needs of museum-libraries and living zoological exhibits in our parks. It is rarely recognized among these officials just what this implies, and they do not always realize that such a combination of museum, zoological exhibit and library should be planned very differently from the corresponding city institutions. By all means its exhibits should be rigidly confined *solely to the resources of the particular park,* and it should be primarily intended to stimulate visitors *to go out into the park itself* and see as never before. But in the case of the animal exhibit, it is better to do nothing whatever than to make a failure of it. The library should supplement the museum and be particularly selected to encourage an outdoor acqaintance with the park. I have elsewhere emphasized the main features of such a local museum ('08a). The plans of Graves ('19) for a "Nature Library" are easily adapted to particular parks. Such a library should be viewed broadly as containing photographs, facilities for lantern talks, and moving pictures. Such a museum-library or its branches, should be so located that it will become the natural meeting place for all information about our parks. The facilities of the museum-library, supplemented by field work and lectures, will make it the natural headquarters for the guide service.

The zoological exhibit in the park should be devoted exclusively to the kinds of animals natural to the region, and in this it is in striking contrast with a city zoological garden. Too much emphasis cannot be put on this point. The basic idea of such a collection is to give the visitors, in a limited time, a good close-up view of the native animals, and to encourage their interest in them as they tour the parks or camp there (Adams, '21a, p. 70).

No opportunity should be lost in teaching this visiting public the *reasons* and methods necessary to properly care for and appreciate animals. Our parks' only safety, in the long run, is an intelligent and appreciative public. They must therefore know the reasons for park rules and regulations, and the better they are understood the greater the chances of their being respected and obeyed.

A moment's thought will show almost anyone that to meet adequately the needs of the public along the lines here suggested will necessitate a special staff of well trained persons.

The park which has so far made the most progress with a museum and zoological exhibits is the Canadian Rocky Mountains Park at Banff, where Mr. Harlan I. Smith has written the best handbook so far published by any park museum ('14).

ADMINISTRATIVE ASPECTS OF WILD LIFE

The administrative aspect of the wild life in our parks is a large and important subject. The problem of properly caring for and using wild life to the best advantage in our parks is becoming increasingly more serious and difficult. With the increasing number of park visitors new problems are coming up all the time. As intensive use threatens to wear out the parks recovery can be secured through decreasing the congestion—by enlarging the parks, or by temporarily closing parts of them. With increasing population there is always a tendency to encroach upon the wilderness. Thus to maintain park wildernesses can only be accomplished by a struggle, and the eternal vigilance needed to preserve our liberty is the same price that must be paid for the free, wild nature of the wilderness. The wilderness, like the forest, was once a great hindrance to our civilization, but now the tide has turned and wildernesses and forests must be maintained, even at much expense, because human society needs them. Not infrequently have I talked with enthusiastic friends of our parks, who feel that in this struggle the odds are so much against the parks and their wild life, that there is perhaps no use to continue what they feel to be a losing fight. But it seems to me that this is only another aspect of that constant struggle for any high ideal—the only kind worth striving for; this is not at all a peculiar feature of our park and wild life problems.

European experience furnishes us with a number of notable examples of wild areas highly valued because so little of the original conditions remain there. For in spite of the unfavorable situation the appreciation of these original conditions has not yet died out. This is worthy of special mention because of the fear one hears expressed that this is a hopeless cause. In several European countries there are active organizations and endowments devoted to this cause, and even governmental bureaus devoted exclusively to it (cf. Ahrens, '21; Conwentz, '09).

Some of the main administrative problems concerned with wild life are: the maintenance of this resource, including the complete protection of the associated vegetation; the formulation of policies; and the education of the public on wild life interests and the perpetuation of their ideals.

Maintenance of Wild Life.—The maintenance of wild life in parks, in a normal, healthy state, is a relatively new art in America. This involves adequate protection, by rules, rangers or police, and by all the educational devices available. But this protection is not all a question of restrictions, for there is the productive and constructive aspect. Favorable conditions must be maintained, so that the animals will breed normally. If fishing is permitted, the maintenance of the stock in the streams must be looked after continuously, and the supply maintained. Careful supervision of all this must be given and definite policies followed, or great blunders will be made and much damage will be done. A competent park official should supervise all this fish work.

At present, administrators are in a difficult position because of the lack of definite ideas, policies, and public sentiment to support definite programs, and the frequent changes of officials favor a lack of continuity in policies; and furthermore, with such a wobbling policy little is learned from experience.

Education of Park Officials.—At present, the parks suffer to a large degree because they are necessarily in the hands of administrators who, because of their lack of special training, we must consider as amateurs. We have had no profession for this line of work, and some who have had the most training are to be feared to a corresponding degree, because of preconceived, formal ideals, which they with almost religious zeal, slip into the wilderness parks. The ideal of a wilderness park is beyond their ken, because their approach has been from another angle. These persons are of course welcomed in formal city parks, but in our large National Parks, and in the wild parts of State Parks they are liable to be a menace. In the training of such men there has been no adequate recognition of the wild life problems or appreciation of the wilderness.

Another source of difficulty is the lack of trained rangers and nature guides in our parks. Men are needed who have not only a special familiarity with a special subject matter, but as well with the *ideals* of parks. Until very recently we have had no provision for such training in our educational system, and not until adequate provision has been made for this can we expect the detailed work in the parks to be wholly satisfactory. A complete technical staff is needed for our parks, but this fact must be generally recognized before young men will devote themselves to the park profession, and the public must appreciate it fully enough to provide for it in the appropriations.

Need of Formulating Policies.—At present our parks are in great need of definitely formulated policies, even if they are of a provisional nature (cf. Waugh, '18; H. S. Graves, '20). Recently, in connection with efforts to establish new National Parks, the need of bringing out the distinctive characteristics of such areas, compared with National Forests and other public uses of lands, has led the "Council on National Parks, Forests and Wild Life" of New York City (an informal group interested in these problems), to formulate their ideas. This has resulted in a policy leaflet revised to Oct. 25, 1923, while in the same year the Boone and Crockett Club, of New York City, formulated a policy with regard to the protection of big game in the West, which includes the National Parks. Such constructive efforts deserve hearty commendation, but we should bear in mind their provisional character because they have not been based upon the prolonged investigation which their merit warrants. A recent valuable summary of the National Park Service, outlining its history, activities and organization has been compiled by Cameron ('22). The recently organized "National Conference on Outdoor Recreation" is in a position to do excellent work for this cause.

The Forest Service has issued in mimeographed form, from the District Foresters' offices at Albuquerque, Denver and Ogden, "Fish and Game Handbooks," in which certain of the Forest Service policies for wild life are carefully outlined. These policies are naturally not the same as those of the National Parks, but they have much in common; and these handbooks will prove to be of much value to any serious student of the whole park problem who wishes to work out a similar manual for the different National Parks.

A broad, general policy for the parks is not enough; it should be comprehensive, but at the same time it should be worked out in as much detail as is possible, so that in time we will have for our National Parks a manual corresponding, is some respects, to the *Use Book* of the Forest Service. Each State Park or park administration should have a similar policy, which should be published and made a part of the educational data available to the public. It will then be accessible for criticism and improvement. Of course, as many park executives are without adequate help, are liable to political interference, and their tenure short, they are frequently liable to neglect the formulation of these policies, and depend solely upon the laws establishing the parks. Without general policies we can not expect detailed, well-worked-out plans for wild life. Today we have no such published program for the wild life of our National Parks, not even for the fish, which might be expected to precede that for other kinds of animals. The U. S. Fish Commission, in the early days, had no conception whatever of the Yellowstone as a wilderness park, with the fish life maintained as nature left it, and for this reason the Commission was favorable to stocking the waters with various species of exotic fish, and of stocking the streams thoroughly above all falls, where uninhabited by fish, and likewise the isolated lakes. A recent Commissioner of the U. S. Bureau of Fisheries, Dr. H. M. Smith ('17), has sketched a fish cultural policy for Glacier National Park, and has urged that different waters should be reserved for different kinds of fish; that there should be no promiscuous planting; that the introduction of non-indigenous species should be prohibited; and that stocking and fishing should be conducted on a definite policy, which should rest with the federal Bureau of Fisheries. Several of these are admirable recommendations. In my own opinion, however, it would be very unwise to take the administration of the fish out of the hands of the Park officials and place it in the hands of the Bureau of Fisheries, even if the Bureau showed, as it has not in the past, an adequate appreciation of this resource as it should be preserved in National Parks. The Park officials should develop their own staff to handle the fish problems, and they should be more than merely fish culturists, because this work involves many broad biological problems involving other animals than fish, and requiring the ability of trained naturalists. Certain aspects of the fish cultural problems in the Yellowstone have been described by H. M. Smith ('20), and Smith and Kendall ('21). In the report of the Director of the National Park Service for 1920, p. 312, it is stated that in the Grand Canyon National Park, "Bright Angel Creek has been stocked during the year with eastern brook trout." Whether this was done by the Park Service or the Bureau of Fisheries is not stated, but it is just such blunders that should be avoided.

The attitude of the present U. S. Bureau of Fisheries, and of the Park Service itself, has improved somewhat, but still they have, in the main, adhered to the older policies and standards of making angling available everywhere, rather than to maintaining original wild preserves. I have no doubt that this policy has grown up without much deliberation on their part and certainly not after considering the future value for educational and scientific purposes, of large areas of wilderness waters. The idea that forests with big game animals should be maintained as a wilderness, and that there is an advantage in natural wild waters, appears to be a new conception for our parks. Some of the same persons who are very eager to maintain a wilderness for certain purposes have never recognized that others are equally interested in an untouched aquatic wilderness.

Attention has already been called to the need of trained park officials to look after the fish, who are more than fish specialists, and who can fully appreciate the ideals of the Parks, and as well have an extensive knowledge of other Park animals. For example, one of the latest publications of the U. S. Bureau of Fisheries clearly shows this need. Dr. W. H. Rich, Assistant in Charge of Scientific Inquiry, has recently pointed out (*Progress in Biological Inquiries, 1923,* pp. 8–9, 1924) the results of an investigation made by the Bureau of the relation of the white pelican to the trout in Yellowstone Lake, as follows:

"The pelican colony on Yellowstone Lake in 1922 was found to number between 500 and 600 birds, from which about 200 young resulted. For the six weeks of their sojourn on the lake they subsist almost entirely upon the black-spotted trout, the toll taken by each pelican during the season amounting to about 350 fish, and involving, besides, a large loss in trout eggs through the destruction of the breeding fish.

"The pelican represents a strange and interesting ancient type of bird life and it is not desired to exterminate it in the Yellowstone Park, where it is of much interest to tourists. Measures have been recommended, however, for the regulation of its numbers through the destruction, by proper authorities, of a percentage of the eggs deposited on the breeding grounds in the park. The recommendations are now under consideration by the Bureau of Fisheries and the National Park Service."

Let us look into this situation a little further. The U. S. Commission of Fish and Fisheries, the predecessor of the Bureau of Fisheries, established a trout egg collecting station on the shore of the West Thumb of Yellowstone Lake, in 1901, and nine years later (see Report of Acting Supt. Maj. H. C. Benson for 1909, pp. 8-9) the Acting Superintendent reported that over 33,000,000 eggs had been taken. This was the most important egg collecting station for these trout in the world, and the eggs were shipped throughout the neighboring states so that by 1917 the depletion of the small streams between the Thumb and the Lake Hotel was recorded. In 1918 the pelicans and gulls were condemned for serious injury to the trout, and in 1919 it was suggested that a reduction be made in the number of pelicans. The Park Superintendent now recognized the depletion of the waters and the need of increasing fish egg plantings within the Park. At this time the practice of allowing the hotels and camps to take trout for table use was prohibited, this taking effect on August 15, 1919. During that summer alone there had thus been used commercially over 7,500 pounds of trout, in spite of the fact that the act of dedication, March 1, 1872, states that the Secretary of the Interior was instructed to "provide against the wanton destruction of fish and game found within said park, and against their capture or destruction for the purpose of merchandise or profit." In 1921 about half the eggs collected were planted in the Park. In 1922 the Bureau of Fisheries conducted its investigation of the pelicans, resulting in the official statement already quoted from Rich, suggesting a reduction of their numbers. During the 22 years that records have been published of egg collecting in this lake, over 187,000,000 trout eggs have been taken, of which an unknown but relatively small number—about 32 millions—were planted in the Park, and of these, 21 millions were planted in 1922 and 1923. The waters are now clearly recognized as becoming depleted. This is clearly and primarily due to the too extensive egg collecting, and to the commercial use of trout on tables; and secondarily, to excessive angling; and lastly, and least of all, to the pelicans and the gulls. The general practice of depleting waters about fish cultural stations, which Kendall ('24) has pointed out, has been in full swing here with its injurious effects, and indicates very clearly that our National Parks are not the places to locate such general fish collecting and distributing stations. The Park authorities have now restricted the shipping of eggs out of the Park, have prohibited commercial use of trout by hotels and camps, and are making greater restrictions on angling. This, I think, fairly states the background needed for consideration of the relation of the pelicans to the trout. Certainly, if angling is to be continued, and to be maintained with the increasing numbers of Park visitors, a fish cultural plant is absolutely necessary; but it should be conducted solely from the standpoint of the welfare of the Park, and not as a general public utility and for commercial use. This was advocated in 1901 and 1902 by Major Pitcher, Acting Superintendent, in his annual reports.

Is this large colony of pelicans worth careful preservation, from the standpoint of future generations of Americans? From several standpoints the pelicans are unique birds, entitled to careful protection, as there are certainly only a very few places, and possibly none outside of Yellowstone Park, where their preservation can be assured. The true status of the pelican, from the public standpoint, cannot therefore be determined solely by its status in the Park. What are the probabilities of its permanent preservation elsewhere? Dr. F. M. Chapman has already pointed out the precarious situation of their other breeding grounds (see *Camps and Cruises of an Ornithologist,* pp. 379-380, 1918). The real purpose of the National Parks is to preserve in them what can best be maintained there. These birds require isolated, protected islands for breeding, just such conditions as exist in Yellowstone Lake. If the Yellowstone Park is to live up to its past reputation as our leading wild life preserve the public must feel assured that they are in safe keeping and cannot be menaced by excessive fish egg collecting, commercialization of trout for hotels and camps, or by excessive angling.

The destruction of a certain amount of trout by the pelicans is a necessary phase of the maintenance of wild life in the Park, just as is the growth and protection of forage and the cutting of hay in relation to the maintenance of elk and bison, or the destruction of insects and rodents by the bears, or even the collection and planting of trout eggs. Before any restrictive or drastic measures are taken it is eminently wise to have much more complete information about them. When trout eggs were first collected in the Park the supply was considered "inexhaustible," but now we know better. The breeding of pelicans, about which we know very little, is vastly more difficult than that of trout, so that at present the only safe method is to greatly increase a proper kind of fish culture, and to absolutely prohibit the shipment of trout eggs outside of the Park. There is an abundance of eggs to stock the Park waters and to feed all the pelicans and the gulls. Furthermore, it will be necessary to make greater restrictions on the catch, as we know how to do this, rather than to interfere in any way with the pelicans, about which we know so little, and whose future is precarious.

The Wilderness Policy.—The Council of the American Association for the Advancement of Science, at the Toronto meeting in December, 1921, passed the following resolutions, which have a very direct bearing on the policy of our National and State Parks in maintaining their native plants and animals in natural conditions. These resolutions read (*Science,* N. S., Vol. 55, p. 63, 1922):

"*Whereas,* one of the primary duties of the National Park Service is to pass on to future generations for scientific study and education, natural areas on which the native flora and fauna may be found undisturbed by outside agencies; and

Whereas, the planting of non-native trees, shrubs or other plants, the stocking of waters with non-native fish, or the liberating of game animals not native to the region, impairs or destroys the natural conditions and native wilderness of the parks;

Be it Resolved, that the American Association for the Advancement of Science strongly opposes the introduction of non-native plants and animals into the national parks and all other unessential interference with natural conditions, and urges the National Park Service to prohibit all such introductions and interferences."

The Ecological Society of America, a leading organization of naturalists interested in outdoor natural history, has also passed similar resolutions (*Ecology,* Vol. 3, pp. 170-171, 1922).

In spite of the public announcement of these resolutions, only recently it was announced by a representative of the National Geographic Society that he planned to secure plants from Tibet, "suitable for planting in Glacier National Park" (*Science,* N. S., Vol. 58, p. 460, 1923).

As the importance of maintaining wild, natural parks, is not sufficiently appreciated, it is worth while to briefly summarize some of the main reasons for this policy:

1. With our increasing population wild lands and their native population of plants and animals are decreasing at an alarming rate. Much of Europe has undergone this demolition. The public has heard much of the decrease of insectivorous birds, because of their relation to forest and agricultural crops, and sportsmen have become aroused about fish and game, but there are many other plants and animals, also of great value, in defence of which we hear little. Even educators have become but slightly alert to the danger of teaching about nature only in cultivated fields and artificial parks.

Wild lands, with their native plants and animals, are as worthy natural monuments as are other valuable features in our parks. These have great scientific and educational value (cf. Grinnell and Storer, '16). Today, all wild lands and wild waters tend to become more remote so that before long they will be inaccessible to the average citizen. Sportsmen and anglers are being shut off from private lands and in turn they have begun plans to reserve wild public lands for hunting and fishing. We readily grant the validity of this, but our educational needs for children and scientific needs of both children and adults are certainly not a less worthy reason for the preservation of wilderness lands and waters.

2. If parks are to be managed so that they may be passed on to

future generations unharmed, they must in the main remain wild. No one can safely assume that he is able to tell how valuable these regions will become in the future, when properly stocked. When once a plant or an animal becomes *extinct* it is beyond human power to restore it. We can well afford to play safe in such matters. Sir Harry H. Johnston, a member of the Honorary Advisory Council of the Roosevelt Wild Life Station, has very well said that:

"The world will become very uninteresting if man and his few domestic animals, together with the rat, mouse, and sparrow are its only inhabitants. Man's interests must come first, but those very interests demand food for the intellect. Aesthetically, the egret, toucan, bird of paradise, grebe, sable, chinchilla, and fur-seal are as important as the well-dressed woman. The viper, lion, tiger, crocodile, wolf, vulture, and rhinoceros have all their places to fill in our world picture. They are amazingly interesting, and therefore their destruction should only be carried out to the degree of keeping them in their proper sphere."

The whole situation is thoroughly sized up by H. G. Wells in his *Outline of History,* as follows:

"But there will be no diminution of adventure or romance in this world of the days to come. Sea fisheries and the incessant insurrection of the sea, for example, will call for their own stalwart types of men; the high air will clamour for manhood, the deep and dangerous secret places of nature. Men will turn again with renewed interest to the animal world. In these disordered days a stupid, uncontrolled massacre of animal species goes on—from certain angles of vision it is a thing almost more tragic than human miseries; in the nineteenth century dozens of animal species, and some of them very interesting species, were exterminated; but one of the first fruits of an effective world state would be the better protection of what are now wild beasts. It is a strange thing in human history to note how little has been done since the Bronze Age in taming, using, befriending, and appreciating the animal life about us. But that mere witless killing which is called sport today, would inevitably give place in a better educated world community to a modification of the primitive instincts that find expression in this way, changing them into an interest not in the deaths, but in the lives of the beasts, and leading to fresh and perhaps very strange and beautiful attempts to befriend these pathetic, kindred lower creatures we no longer fear as enemies, hate as rivals, or need as slaves. And a world state and universal justice does not mean the imprisonment of our race in any bleak institutional orderliness. There will still be mountains and the sea, there will be jungles and great forests, cared for indeed, and treasured and protected; the great plains will still spread before us and the wild winds blow. But men will not hate so much, fear so much, nor cheat so desperately—and they will keep their minds and bodies cleaner."

3. Original or virgin conditions are particularly suitable for teaching and for scientific study (Adams, '08, p. 147; '13, pp. 23-35), because they are relatively simpler and less confused than when man interrupts the natural order by his confusion and destruction (cf. Sumner, '20; Shelford, '20). We have learned that the natural behavior of animals in nature is very different from those caged and in confinement. Our large animals are of the greatest interest in our parks, and any complete scientific knowledge of them necessitates that they be studied in the wild state. The public must therefore provide the proper conditions for them in order to derive the most from them, both from a popular and a scientific standpoint (cf. Hahn, '13, p. 171). No animal can be thoroughly understood independent of its normal environment. It is therefore not enough merely to preserve these animals in zoological parks and in cages. Confined animals have a great educational value, without doubt, but they are not an adequate substitute for wild animals in nature. There must also be a permanent wild supply to maintain the zoological gardens of the world.

Although there are considerable areas of the National Forests which are likely to remain virgin wilderness, this is not a sufficient guarantee that we will have all we need. The chances are that in the near future silvicultural foresters will, with increasing emphasis, strive to retain valuable examples of representative virgin forests within our National forests and State forests, in their original condition for special study. These areas will also act as preserves for many animals, but they will not necessarily provide for the larger animals unless they coincide, as they well might, with wild life preserves. Some foresters have already observed the need of a forest "wilderness" as a part of the recreational policy of the National Forests (Leopold, '21), and others for the purpose of teaching and investigation (Ashe, '22; Pearson, '22), and if such areas give complete protection to both plants and animals great progress will be made. The grazing of domestic animals must be restricted or excluded from such preserved areas or the herbaceous vegetation will soon be greatly modified (Korstian, '21). The experiences in the

National Forests clearly show just what will certainly happen in our National Parks, from the wilderness point of view, if they are not strictly guarded. These experiences also clearly show that great caution must be exerted, even with the present customary grazing in our National Parks. Without question this should be prohibited, and the forage should be reserved for the game in the Parks. Until prohibited, the grazing should be under the close supervision of a range ecologist. The same ideas apply even to living and dead trees, that at any time may be cut in these National Parks. At present we have only one official park forester in the great National Parks, and very few connected with State Parks; and not all foresters are alert as to the value of virgin forests. European experience (Conwentz, '09, pp. 118, 131) has clearly shown that the clear cutting of forests is very harmful to many kinds of native plants, and this is equally true for many animals, for we know that the vegetation exerts a powerful influence upon most forest animals.

In some State Parks commercial forest management is practiced, and this is very desirable under certain circumstances if the commercial forests and the preserves are well balanced, and if provision is made for corresponding management of the preserved areas. At present, great caution must be observed not to confuse the management of these two types of forest. A proper balance should be secured, and then the commercial forest might well be made a source of supply for the local wood-using industries, and a means of securing revenue for the maintenance of the whole park (Adams, '21, p. 64). In time, the park authorities may find it necessary to charge a small fee for their use, and a forest park with funds from the timber and from a fee or license for the use of the preserve, might secure enough revenue to do much more constructive work than one depending solely upon taxation and gifts. This possibility is so important that it deserves more attention than it has received in the past. The new Allegany State Park in New York was planned upon such a program.

The chances are that National Parks will never be numerous enough and widely enough distributed to give us a sufficiently large sample of our native flora and fauna to meet all scientific needs. This is one reason why State Parks in the East are in a position to do much more, on the whole, than National Parks. But it is not enough, as has been said before, simply to preserve the species. We need, just as imperatively, samples of their normal habitats; and to make these safe, the samples must be fairly large and widespread, or devastating fires or incompetent officials are liable to cause an excessive loss. There should not be too much concentration.

An excellent example of the need of natural conditions for scientific studies is seen in the case of the timber line on mountains. A few years ago the American plant ecologist, Shaw, was making a special study of the causes of the high timber line on mountains and pointed out that:

"Most of the work on the subject of timber line has been done in Europe, and there the conditions are peculiarly unfavorable. For in the Alps and Pyrenees, the timber line has been greatly modified by human agencies. When an observer has first to decide whether that which is before him is due to natural causes or not, his conclusions stand a double chance of error. Certain European workers have published elaborate tables showing the precise altitude of timber line and other facts of vegetation for parts of the Alps. When it is remembered that flocks and shepherds have played a considerable and not easily determined part in bringing about present conditions, the value of such tables is less apparent. A study of wooded mountains where conditions are entirely undisturbed would, therefore, seem desirable. . . . So far as first-hand knowledge goes, I may say that in a walking trip of several weeks through the Alps, I had much difficulty in finding an illustration of timber line that was beyond suspicion of being artificially caused. I did, however, see the shepherds pulling up little trees near timber line in a manner which left no room for speculation as to its efficiency." (*Plant World*, Vol. 12, pp. 63–64, 65; 1909.)

ENDOWMENT FOR EDUCATION AND RESEARCH

The greatest advances in science and education are today made by the combination of private endowments and public support. Our Smithsonian Institution was no doubt an influential agent in teaching Mr. Carnegie and Mr. Rockefeller the value of endowments for research. The American Museum of Natural History and the New York Zoological Society are examples which show that semi-public institutions, supported by taxes and by endowments, make the most rapid and constructive advances in their respective lines. The Palisades Interstate Park, supported and built up by private gifts and State funds from both New York and New Jersey, under the guidance of Mr. George W. Perkins taught the whole world the use of a great public park for the peoples' welfare along several new lines. This method of combining private and public support seems at present to appeal to the idealism of large-minded men and makes it possible for such institutions to make the greatest progress. It is important to note that in such a plan *no great success* can be secured unless there can be enlisted in the cause men of real practical idealism of a very high type, *combined* with sound practical judgment. Without such leadership routine work can be conducted along conventional lines but no great advances can be expected.

The time has come when we must begin an educational campaign for large endowments for the educational and scientific work in our National and State Parks. Of course, much can be done by cooperation with various individuals, the colleges, universities, and scientific societies, particularly with some of the State universities, especially if urgent requests are made to them for cooperation. They are likely to respond best when sought. But it is likely to take some time for these institutions to become acquainted with this phase of work, as most of them, even today, have but a faint realization of outdoor biological problems and their application to parks. Fortunately there are a few marked exceptions.

The parks need such funds primarily for three purposes:

1. They need a technical *scientific staff* to solve their own scientific problems as much has they need lawyers and engineers. The need exists — but it is only slightly realized,— and in the main only those who are taking a broad view of the situation are aware of the conditions.

2. They need an *educational staff* to build up their local museum-library, for nature guides, and to supplement and aid in the training of rangers, who should also be trained men. This staff should be the mainstay for popular lectures,— lantern and moving picture lecturers who will arouse intelligent appreciation of the resources of the parks.

In general, the scientific and educational staffs should be *distinct* because the two kinds of work can not be done at the same time, and the staff can not be expected to divide its attention successfully. An executive does not expect his lawyers or engineers to drop their work at any moment and give a popular talk, or to conduct other extraneous work, and the same applies to the scientific staff.

3. The educational and scientific staffs should be large enough to include certain men who could devote their whole time to the

practical and technical problems that demand immediate attention, closely related to the administrative, rather than to the scientific or educational aspects of park work. The main reasons for advocating this as a distinct group is that in *practice* it is rare that sufficient funds can be obtained to secure men who are versatile enough to cover *so large a field*. Furthermore, research is a special kind of work that requires uninterrupted attention to secure the best results (cf. White, '23, pp. 23–25); it is therefore safer to plan for larger staffs.

It is generally difficult in administrative circles to appreciate that first-class men who are willing to have their work continually interrupted by all sorts of administrative breaks can only rarely be secured. These men must, to get the best results, be protected from such interruptions. It is the administrator's first business to adopt methods that will permit his organization to solve its problems, and this is one of his duties which too often is undervalued.

To provide for such a staff for our Parks will necessitate a considerable endowment. To be concrete, the Yellowstone and the Yosemite alone now need a full million dollars each, the income of which should be devoted exclusively to research and education in these respective Parks. These funds should be independent of the scanty Congressional appropriations and would tend to make them much more effective, and they would do much to educate the public in an intelligent use of such parks. Who will question for a moment that today we would not have the Katmai National Monument had it not been for the scientific investigations which have been made and are being continued by the National Geographic Society under the leadership of Griggs?

The Palisades Interstate Park needs just such an endowment and such a staff, as I learned when cooperating with the Commissioners as a representative of the Department of Forest Zoology in the New York State College of Forestry. During the seasons of 1918 and 1919 the field parties of the Department of Forest Zoology and of the Roosevelt Wild Life Forest Experiment Station conducted their investigations on wild life in this Park (Adams, '19). This was done through Mr. George W. Perkins, in immediate cooperation with Mr. Edward F. Brown, Superintendent and later Director, of the Camp Department of the Park. Later, a short time before Mr. Perkins' last illness, a plan was presented to him for field studies to be conducted cooperatively by the Park Commission and the Roosevelt Wild Life Station. The idea was to conduct just such investigations and demonstrations as had already been started in the Park during the previous seasons (cf. *Roosevelt Wild Life Bulletin,* Vol. 1, p. 53, 1921).

Our party began work there by making a study of the fish, as a basis for properly managing the waters (cf. Adams, Hankinson and Kendall, '19), and preparing guide booklets on birds for the park visitors (Silloway, '20). But we were soon importuned to study some method of controlling the leeches in one of the most frequented bathing lakes, and incidentally controlling the mosquitoes (by means of fish), and finally to aid in the control of the algae causing "water bloom" which also annoyed the bathers. These investigations were made by Moore ('22, '23), and Smith ('24). In the effort to control the "bloom," it was found that the copper sulphate also killed the fish. It then became a study of how to harmonize all these interests, and this series of problems could not be solved without the aid of scientific men. It will be seen that these are relatively new kinds of park problems, and that they are a direct result of intensive use occasioned by the proximity of the Park to our largest city. These new park activities are due primarily to Mr. Edward F. Brown's ideas of camp development which Mr. Perkins accepted (cf. Jessup, '19, p. 159) and organized in the Park on such a large scale that it became the largest camping park in the world (cf. Silloway and Brown, '20).

The main advantages which the public will derive from such a staff of experts ought to be self-evident. It is rarely that one must show that a lawyer or engineer is needed for a technical problem, but how to gain similar assistance for the educational, scientific and like problems in the parks is not quite clear, even to some of our best park leaders. This is natural when we recall that most of those engaged in park work have gone into it without a professional park training, and for this reason, although they may have a special interest and experience in some phase of the work, as a rule they do not have a comprehensive grasp of the problems, or the technical knowledge needed for many diverse undertakings. For these reasons it is worth while to summarize some of the major advantages of such a professional staff:

1. Trained men are necessary for scientific, educational and technical work. They must have the time and facilities to master these problems and to adapt them to the situation. We have

no reason to expect scientific services free, and the public has no more right to expect that such technical services will be contributed, than legal or medical aid. Moreover these men must be devoted exclusively to their own special work.

2. The wild life of the parks requires constant, all-year-round attention. A great number of our parks will be more and more patronized the year round when the people become educated to it. With this increasing patronage there will constantly develop new problems for solution and supervision.

3. It is only such a staff that can be expected to present, in suitable popular form, the natural history resources of the parks. These popular accounts should be presented from many angles if a large public is to be reached to advantage. It is a common error to assume that there is only *one* popular form of approach; a multiple approach should be carefully cultivated by different types of students and authors.

4. There are certain problems of park administration that should first be solved as scientific problems, and then executed under technical supervision, such as the care of fish, game and birds, mosquito control, and the management of the forests. These are examples of the problems, which, with increasing use, the natural resources will require. They call for a kind of supervision which the average executive can not be expected to know about, and yet these are just the points that a special staff will know about, and their advice and help are therefore necessary.

In concluding these remarks on the need of endowments it is important to emphasize that the management of wild life is a more or less elusive subject for the public and the administrator to understand; and it cannot be understood merely by inspection—it must be known intimately. Otherwise, great damage may be done by neglect or ill-advised measures before it is realized that anything is wrong.

The real difficulty is that wild life and its problems suffer from just the same cause as the human animal in our democratic system of environment. As Walter Lippmann has recently said: "For the troubles of the press, like the troubles of representative government, be it territorial or functional, . . . go back to a common source: to the failure of self-governing people to transcend their casual experience and their prejudice, by inventing, creating, and organizing a machinery of knowledge. It is because they are compelled to act without a reliable picture of the world, that governments, schools, newspapers and churches make such small headway against the more obvious failings of democracy, against violent prejudice, apathy, preference for the curious trivial as against the dull important, and the hunger for sideshows and three-legged calves. This is the primary defect of popular government, a defect inherent in its traditions, and all its other defects can, I believe, be traced to this one." (*Public Opinion*, pp. 364-365, 1922. New York.)

SUMMARY

In concluding this discussion, I wish to summarize my main points as follows:

1. We will derive benefit from wild life in our parks in direct relation to what we devote to it. We need to recall that living organisms respond readily to fair treatment.

2. In general, wild life can prosper only with the parks as a whole.

3. Wild life is a very valuable resource in any wild park, and it is generally so recognized by the public.

4. The National Parks should remain a virgin wilderness for educational, scientific and recreational purposes.

5. State Parks should retain wilderness areas, as well as include commercial forests, the proportion depending somewhat on local conditions.

6. In relating the wild life to the public a variety of experimental popular publications is advocated. Technical reports are needed for park officials. We need a distinctive park literature.

7. Field excursions conducted by carefully trained guides are advocated, to develop trails and a trail literature, and as one of the best methods for teaching the appreciation of natural resources.

8. A museum-library, devoted exclusively to each particular park, should be equipped for exhibits, lectures, demonstrations, lantern slides and moving pictures, to arouse interest primarily in the local park. This should be the headquarters for the guide service.

9. A local zoological exhibit, of the park animals *only*, would stimulate interest in the wild life of the park, but it should not be conducted like a city zoological garden.

10. The maintenance of a virgin wilderness park is a very difficult, but not a hopeless problem, if intelligent public sentiment is developed in its behalf.

11. Specialized education and training of park officials of all kinds is urgently emphasized. As a means to this end park policies should be formulated and published with a full explanation of park ideals.

12. The far-reaching importance of preserving original habitat conditions for plants and animals, from the educational, aesthetic, scientific and recreational viewpoints, is strongly emphasized. The value of State Parks in this plan is very important.

13. To develop public appreciation and conservative utilization of parks, large endowments are needed to supplement public support. The greatest progress is made where public and private aid is combined with high and practical idealism. A movement should be started for endowments for educational and scientific work in both National and State Parks.

14. Park endowments are perhaps one of the best means of developing a technical staff for our parks. The preservation of wild life and other natural resources requires supervision by such specialists.

15. A fact-finding or research organization is a necessity, not a luxury, in dealing with park wild life problems, and will make it possible to apply the scientific method to their solution.

16. Wild life suffers from the major defects of our democratic system of control, and its welfare depends fundamentally upon improvements in this system.

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NATIONAL PARKS POLICY AND WILD LIFE

"The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

An act to establish a National Park Service, and for other purposes. Public — No. 235 — 64th Congress, (H. R. 15522); 1916.

"For the information of the public an outline of the administrative policy to which the new Service will adhere may now be announced. This policy is based on three broad principles:

'*first*, that the national parks must be maintained in absolutely unimpaired form for the use of future generations as well as those of our own time;

'*second*, that they are set apart for the use, observation, health, and pleasure of the people; and

'*third*, that the national interest must dictate all decisions affecting public or private enterprise in the parks.'"

FRANKLIN K. LANE,
Third Annual Report, U. S. National Park Service, p. 361; 1919.

Drawn by Edmund J. Sawyer.

PLATE 26. THE GRIZZLY, OR SILVERTIP, OF THE YELLOWSTONE WILDERNESS.

THE BIG GAME ANIMALS OF YELLOWSTONE NATIONAL PARK*

By Edmund Heller

Collaborator, Roosevelt Game Naturalist, Roosevelt Wild Life Forest Experiment Station, Syracuse, New York.

CONTENTS

INTRODUCTION

One may have a preconceived idea that people who visit the Yellowstone National Park center their interest on the geysers that spout and play and fill them with awe by their wonderful hydraulic displays. Nothing, however, is farther from the truth. The summer tourist probably is most fascinated by the sight of the two species of Park bears. The black or brown bear is a friendly animal and a never-ending source of wonder and amusement; and the shy but powerful grizzly expresses in every move-

* This is the second of a series of papers on the wild life of Yellowstone National Park which has been made possible by gifts to this Memorial Station from the joint friends of Theodore Roosevelt and of wild life conservation. The initial aid for this plan came from Mr. Howard H. Hays, President of the Yellowstone Park Camps Company. Mr. Heller and his assistant, Mrs. Hilda Hempl Heller, contributed their services; Mrs. Corinne Roosevelt Robinson and an anonymous friend contributed funds; and Mr. Kermit Roosevelt loaned his naturalist's camera for the photographic work. I gladly avail myself of this opportunity on behalf of the Roosevelt Wild Life Station to thank these persons most heartily for their cooperation. (Cf. also *Roosevelt Wild Life Bull.*, Vol. 1, No. 1, pp. 96–99.)— The Director.

ment an alertness and a spirit of independence that instantly commands respect. The tourist's conversation follows the promptings of his heart, and bear talk flows from his lips far oftener than any regarding the geysers or other inanimate objects.

The accent is on bears, rather than other animals, only because the bears are seen more frequently and are easier to scrape acquaintance with, either along the highway or in the vicinity of the camps and hotels. Almost any species of large mammal is more alluring to the visitor in Yellowstone Park than even the geysers, notwithstanding the wonderful and varied displays of these natural gushers.

It is doubtful whether the men who fifty years ago set aside a wilderness square about the geysers for their official protection ever dreamed that these four boundary lines would one day enclose the greatest game refuge in the country. Today, Yellowstone Park harbors more big game animals and in greater variety than any other park or wild life sanctuary in the United States. And yet unfortunately its present boundaries and its altitude are such that it is almost impossible as an all-the-year-round game refuge. It was an accidental circumstance, a geographical providence, that some of our big game mammals originally ranged in summer in the great geyser region and were thus allowed to live their lives and reproduce their kind in relative seclusion. It is, however, a strange paradox which compels us to starve and freeze some of these game animals annually in order to preserve the remainder. For the Yellowstone is actually a cold storage Park for six months of every year. From December to late April or May it is covered by a heavy mantle of snow which chills the grazing animals and buries the vegetation on which they depend for sustenance.

The bears have partly solved the problem of winter by hibernating; but no bear can endure hibernation more than five or six months, and the first of April usually marks the end of his winter sleep. About that time Bruin emerges into the white world of early spring with an aching and hollow interior, and straightway visits his favorite hotel, which he finds closed, silent, and absolutely lacking in hospitality. He must either feed on the carcasses of elk and other game that have succumbed to the cold or lack of forage during the winter, or else wander down and out of the park to the snowless lower country where he can dig roots or secure small animals. A bear's life is not too easy in the Yellowstone, even

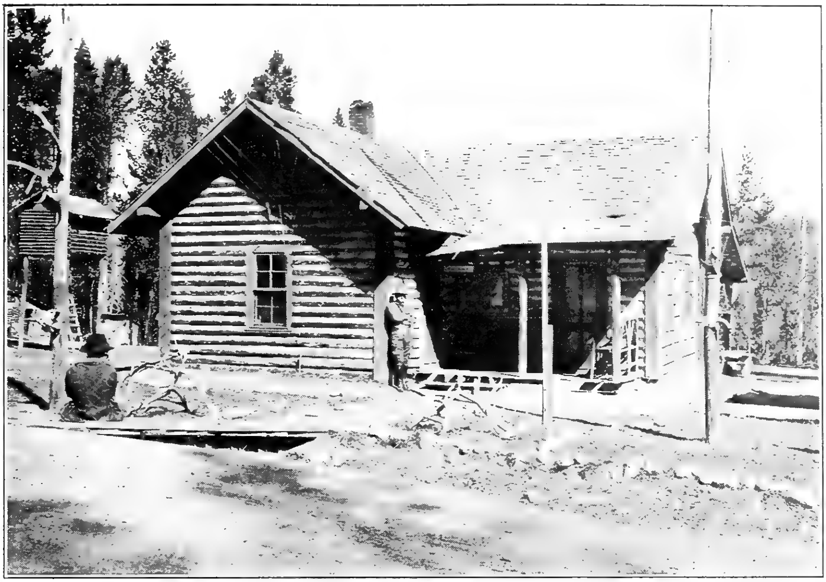

Photo by Edmund Heller.

Fig. 46. The old Canyon Ranger Station. This was replaced in 1922 by a commodious log building combining the ranger headquarters with a tourist recreation hall.

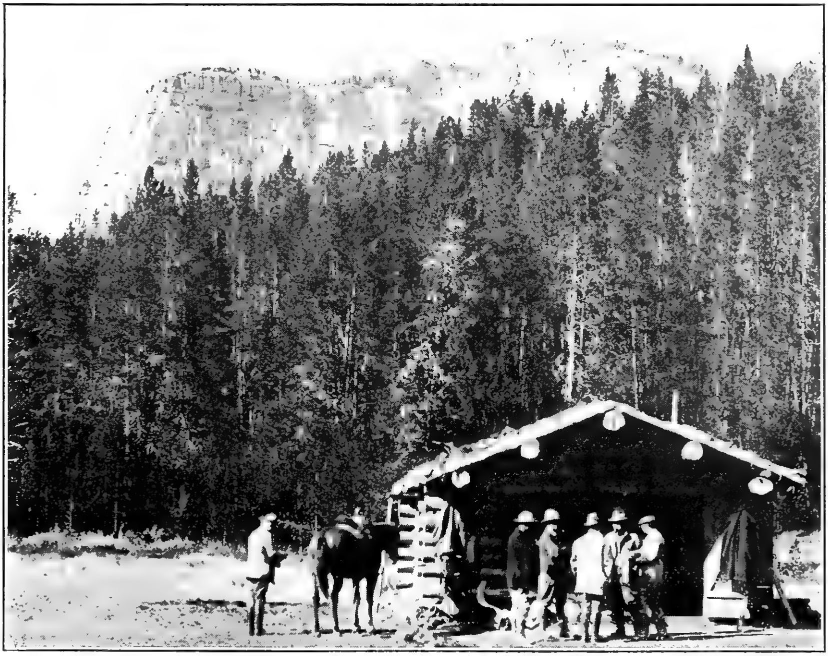

Photo by Edmund Heller.

Fig. 47. A "Snowshoe Cabin" for winter ranger patrol, near the Park boundary on Upper Yellowstone River, in the heart of the best moose country. Secretary of the Interior Fall and party, September, 1921. Peaks of "The Trident" in background.

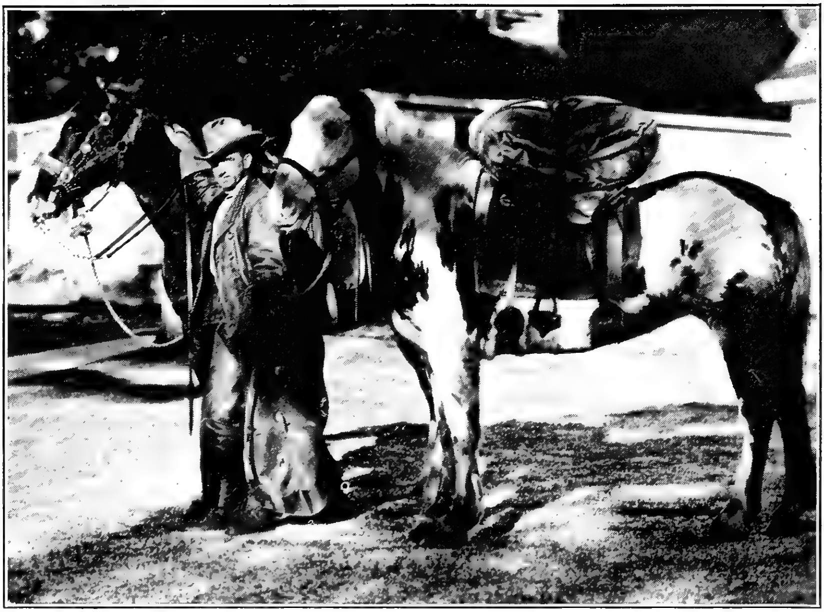

Photo by Edmund Heller.

Fig. 48. Chief Ranger Woodring starting on a trip of inspection to the station at Hellroaring Creek on the range of the northern elk herd.

Photo by Edmund Heller.

Fig. 49. Some of the men on the permanent ranger staff. These are the hardy mountaineers who guard the big game animals of the Yellowstone and make the lonely winter patrols of the Park boundaries.

though he is a pensioner at the hotels and camps during the tourist season. There is always a hard spring to weather if he remains in the Park; but if he wanders outside he must dodge the bullets of ranchmen as best he can until with the coming of June the Park hostelries open and he can return to his happy summer home in the forests near their refuse dumps.

The hoofed animals, being less fortunate by nature than the bears, must struggle through the winter precariously, but if the snows are not too deep and the grass too sparse beneath, they manage very well. Park officials now have the awkward problem thrust upon them of saving or preserving game animals in great numbers in an area which Nature never intended for a winter game refuge. Every fall the Park staff has a hard fight to prevent the herds of elk and the diminishing band of antelope from wandering out of the Park into the neighboring States where they are sure to be destroyed in one way or another, legally or illegally. This exasperating situation can be remedied in only one way, that is, by enlarging the Park to the north and to the south along the lines of march of the downward migrating animals, so as to include sufficient winter range to enable them to survive the severest season. This proposed enlargement of Yellowstone Park, making a better geographic unit, will enable the ranger force to more readily protect the game from hunters who now line the boundaries during the open season and strive to slaughter every individual and band that ventures outside in search of food.

In the fall of 1921, I visited a National Park, the Yellowstone, for the first time. At the invitation of Dr. Charles C. Adams, Director of the Roosevelt Wild Life Forest Experiment Station of the New York State College of Forestry, I engaged in a preliminary survey of its big game animals for this institution. I had met with the game species of the Yellowstone elsewhere in the hunting field years ago and had collected most of them as specimens for our natural history museums, but I have never before passed time more pleasurably and profitably than in this present natural history investigation. I learned more about the habits of the animal species observed during these few months than in all my previous hunting experience.

As our oldest and best stocked game sanctuary Yellowstone Park is an ideal field for the study of large mammals. For forty years elk, bison, antelope, mountain sheep, deer, moose, bear and beaver have lived here in comparative safety, and their protection is now almost absolute so long as they do not stray outside the Park.

They exist under very nearly original conditions, and their real characteristics and habits can be studied in their natural environment to great advantage by the sympathetic lover of wild life. To a hunter-naturalist there is no more attractive field for study than that of the habits and behavior of these game animals,—creatures that have been systematically pursued and have withstood extermination chiefly by their admirable intelligence in the uneven struggle against man.

My explorations and investigations in the Park covered a period of some fifteen weeks in late summer and autumn, August 13 to November 17, 1921, with the exception of a fortnight in October (the 8th to 21st) spent with Hon. Stephen Mather, Director of the National Park Service, on a motor trip to the canyons of Utah and the north rim of the Grand Canyon of the Colorado. While I was absent from the Yellowstone on this latter journey, my wife, Mrs. Hilda Hempl Heller, remained in the Park engaged in animal photography in the Lamar Valley and in the Mammoth Hot Springs district. Mrs. Heller assisted me in photography and field work throughout my stay in the Park, with the exception of the last three weeks, which I spent alone.

The routes we traversed in the Park totaled over 1200 miles, of which less than 100 miles were made by saddle-horse and the rest by motor car. About thirty days were spent in mountain climbing and following the trails on foot. Our operations were limited to central Yellowstone Park in the vicinity of the highways that connect all the camps and hotels. The principal tourist camps were visited and the bulk of our time was devoted to making the acquaintance of the game animals which haunt the neighborhood of these resorts, particularly Camp Roosevelt, Canyon Camp and Mammoth Camp. Several trips were also made to the Buffalo Ranch on the Lamar River. Mr. Howard H. Hays, President of the Yellowstone Park Camps Company, was our good host at the camps, and he and his staff assisted us in many ways. We are indebted to him for many motor rides and for much personal good cheer, his spirit typifying the good fellowship and democracy of the West.

Mr. Chester Lindsley, the Assistant Superintendent of the Park, met us at the West Yellowstone entrance and drove us through the Park to Mammoth Hot Springs, formerly the military station of Fort Yellowstone. Our first day took the form of an elaborate initiation, a tour of over 120 miles with short stops at famous

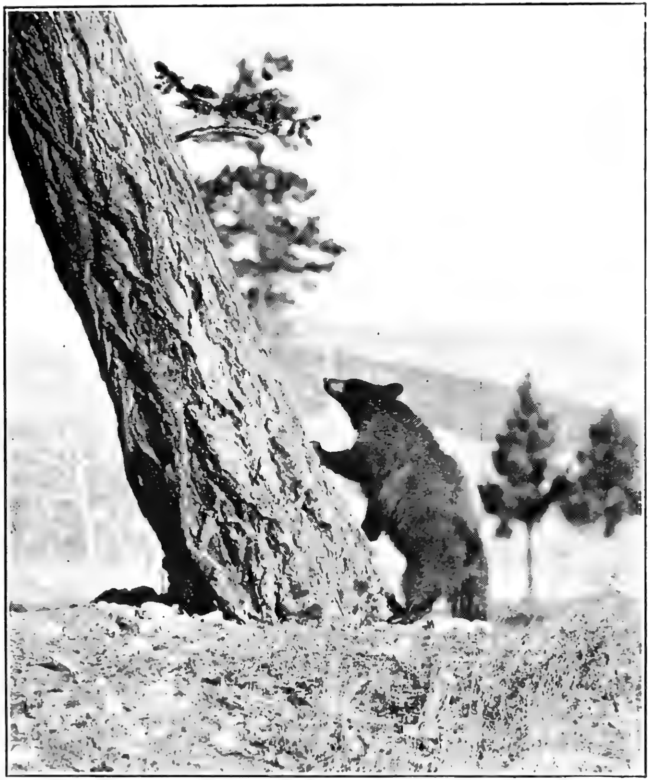

Photo by Edmund Heller.

Fig. 50. A two-year-old "cinnamon" bear at Camp Roosevelt, Yellowstone Park. The black bears clamber up the trees with the agility of a cat, but adult grizzlies are unable to climb, and their cubs rarely do so.

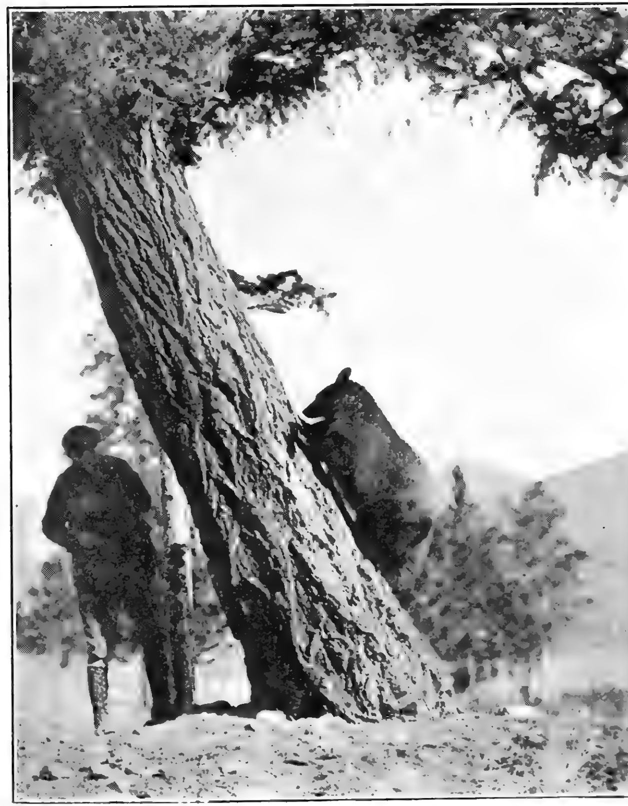

Photo by Hilda Hempl Heller.

Fig. 51. A game of hide and seek. The author hiding from a "cinnamon" bear at Camp Roosevelt. The brown or cinnamon bear is merely a color phase of the black bear.

Photo by Edmund Heller.

Fig. 52. A mother black bear and cub dining on garbage "a la carte." Many bears live in the vicinity of the camps and hotels during the summer as a result of protection, and feed daily at the refuse dumps.

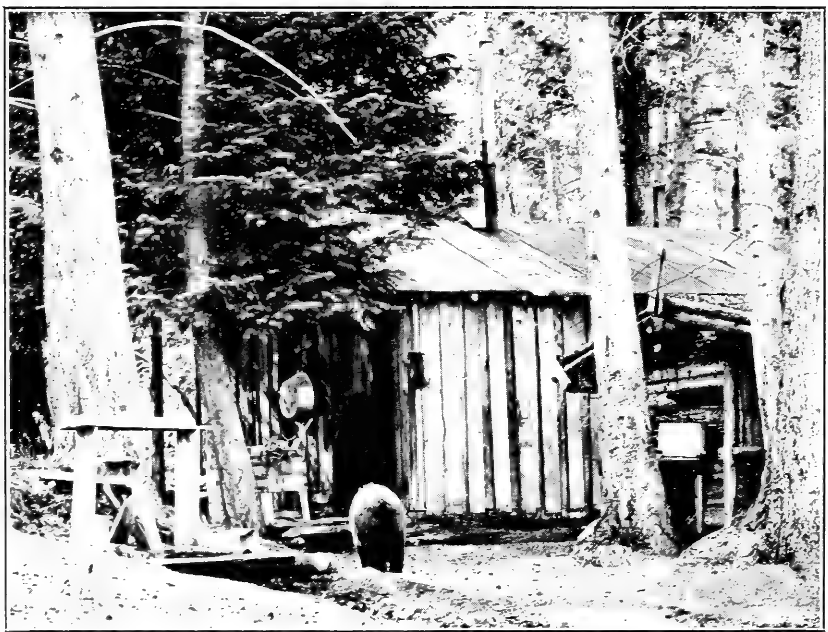

Photo by Edmund Heller.

Fig. 53. Young bears stalking the caretaker's cabin at Camp Roosevelt. Note the barbed wire entanglement on roof of log storehouse. In the fall, just before hibernating, both black bears and grizzlies frequently break in where food is stored.

geysers and colorful springs and waterfalls, and included a ride along the shores of beautiful Yellowstone Lake during a sudden hail squall of great violence. We had begun our journey in the bright sunshine of a summer's morn and had viewed almost every species of hot water display, and then at noon a hailstorm overtook us and we were shown what cold water and ice could do! After lunch at the Lake Hotel we continued our journey over the meadows of Hayden Valley, following the meandering Yellowstone River to its Grand Canyon. We viewed the canyon between showers. It is a beautiful mass of soft yellow coloring, a natural work of art, due to chemical disintegration of the lava rock. The simple beauty of this canyon abyss with its great waterfall has been often misstated and exaggerated in print. It requires no kaleidoscope of colors to describe its beauty. It has a charm all its own, a yellowness that is soft and dominant, and proportions that gladden the eye. We reluctantly stole away from this fascinating canyon and drove into a second hailstorm before reaching Norris Geyser Basin where the youngest and most active of the geyser children play. The place was a mass of steam issuing in many small jets, with one great voice, the Black Growler, dominating the smother of white vapor. Darkness closed down on us at the Golden Gate, a few miles from our destination at Mammoth Camp.

Two days later we were welcomed by Superintendent Horace M. Albright, during a breathing spell in his task of preparing his estimate of the annual budget for all the National Parks. He is a conscientious public servant with a multitude of duties to perform, official and social, which do not permit him a single moment of leisure during the summer tourist season. Throughout our stay in the Park he gave us the use of Park facilities and the assistance of his ranger staff (see figs. 46–49), as well as his own personal attention whenever he could spare time from his official duties. Superintendent Albright is a good father to the game animals, solicitous of their welfare and protection at all times. He regards this last refuge of the grizzly, the vanishing antelope, and the remaining great moose, elk and buffalo herds as a sacred trust. Very efficient game protection is being built up; but the Superintendent's rule is not absolute within the Park, for not a few of the things permitted by the National Park Service pass without his approval. He needs a free hand if the rarer and more valuable animals are to be immune from persecution, the first consideration in the effort to perpetuate these species.

The photographs accompanying this article were for the most part taken by the author with the naturalist's graflex camera which Mr. Kermit Roosevelt used during his expeditions with his father to Africa and South America, and which he generously loaned for the present study. Figure 52 has been reproduced already in *The Minds and Manners of Wild Animals* by Dr. Wm. T. Hornaday, p. 130, 1922; figure 61 has appeared in *The World's Work,* Vol. 45, p. 109, Nov., 1922; and figure 92 was published in *Natural History,* Vol. 22, No. 3, p. 230, 1922. A number of original photographs secured by other observers, and kindly furnished for use in this paper, have been duly credited to them.

I am greatly indebted to Mr. Milton P. Skinner, until recently official Park Naturalist, for numerous suggestions and points of fact drawn from his twenty-five years of painstaking and accurate records of Yellowstone mammals. Also to Mr. Edmund J. Sawyer, present Park Naturalist, from whose drawings, based on two summers' observations of the Yellowstone bears, plates 25 and 26 have been reproduced.

Finally, grateful acknowledgement is here made to those who generously contributed the funds that made possible this preliminary survey of the big game of the Park. An anonymous friend of Colonel Roosevelt and of the Station donated $1000 to defray expenses of the field work. Mrs. Corinne Roosevelt Robinson, who had accompanied her brother Theodore Roosevelt on one of his expeditions to Yellowstone Park, also contributed. The initial support for this project came from Mr. Howard H. Hays whose camps furnished us board and lodging without charge during the tourist season. The warm interest of all who cooperated in one way or another is deeply appreciated by both the author and the Roosevelt Station.

GRIZZLY BEAR OR SILVERTIP

Ursus horribilis imperator Merriam

The sight of a wild free grizzly bear in the Yellowstone excites more awe and admiration in us than does that of any other wild animal. It is here still possible for the tourist to behold that most feared of all American animals, the grizzly or silvertip in his native wilderness. Every evening at sunset you will find gathered on the slope above the Canyon Hotel garbage dump a large party of people, waiting hushed and excited, to get a glimpse of the grizzlies coming to their favorite feeding place. To see the great bears suddenly emerge from the forest in the dusk and come galloping along, their

Photo by Edmund Heller.

Fig. 54. "Old Black Joe," one of the huge black bears at the Canyon garbage dump. It is said that none but a full grown grizzly can master this 500-pound giant.

Photo by Edmund Heller.

Fig. 55. Black bears enjoying themselves amid the ruins of delicatessen. They usually come to the dumps at mid-day, but the grizzlies wait until evening.

Photo by Edmund Heller.

Fig. 56. A friendly "cinnamon" bear being studied by Mrs. Heller and Dan Beard at Camp Roosevelt. It is dangerous to feed any Park bears out of hand; they should never be approached closely except by one familiar with their uncertain moods. The safest rule is to "Leave 'em alone!"

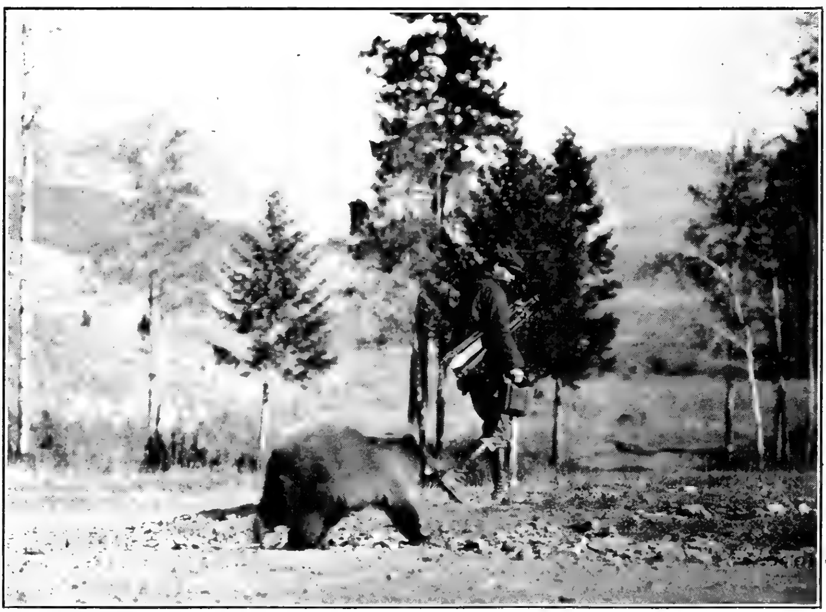

Photo by Hilda Hempl Heller.

Fig. 57. A Camp Roosevelt bear that helped the author take many bear portraits.

rangy forms showing absolute fearlessness and power in every movement as they approach, is the grandest sight in Yellowstone Park.

The grizzly is the undisputed master of the animal world in which he lives. Then why does he wait until sundown to make his appearance at the dump where none may dispute his possession? He is now by instinct nocturnal, and a century-long education through persecution by hunters and other armed men, has made him extremely cautious. The grizzly's bump of caution has grown so large that his awesome glory has almost departed. In the old days he feared no man or beast, and stalked at will over our western plains unmoved by the sight of any enemy. His brain, however, has received many shocks since the Wild West was settled, and today he is as cautious and wary as he once was bold. For fifty years he has lived under more or less complete protection within Yellowstone Park, but his intelligence is not keen enough to grasp the fact that *here* he is safe from the attacks of men, and that the Park is his whenever he chooses to take possession. Unhappily, his experience whenever he passes the boundary quickly destroys any confidence he may have gained. He remains a hungry monarch in a land of plenty. All day he lies dozing in his lair or ranges the solitudes of the lodgepole pine forests of the Park plateau (fig. 90), while the black and brown bears are feeding merrily on fresh-dumped garbage. At sunset he stalks boldly forth into the open and gallops to the dump where, following the daily visits of the black bears, perhaps only a few bones and empty tins await him. What the grizzly needs is more confidence in man while within the Park sanctuary, and recognition of the fact that man is no longer an enemy but a friend. How can we educate this great crafty American mammal to a realization of his social possibilities? Food has not proved to be the magic lure for him that it is for most animals, the spur that impresses the memory,—he has not yet learned the dinner hour. Can we awake him to a diurnal diet and to the "early bird catches the worm" sort of philosophy? Were he protected outside as well as inside the Park, this might be possible.

Today there are less than fifty grizzly bears in Yellowstone Park. The former Park Naturalist, Mr. M. P. Skinner, who is highly expert in census field work, puts the number at forty, which is probably a conservative estimate. Grizzly bears are today no more abundant than they were fifty years ago when the Park was established; they are perhaps less numerous. They apparently wander out of the Park and are killed at a greater rate than they breed. These are the sad facts! How can we safeguard the grizzlies now living inside the Park under protection, so that an increase in numbers will be assured in their only stronghold now left in the United States? Placing food on the dumps after sunset would be one solution, as it would give the grizzly a fair share of the food that should be his, and it would also give him low down in the pit of his stomach a conviction that the Park is his home. The greatest aid in procuring a stay-at-home grizzly would be spring feeding by the Park Service from about April 1, when the bears emerge from hibernation, to June 20, the opening date of the hotels and camps. The spring is the saddest time of the year for the bears, who emerge from their hibernation gaunt with hunger and with a determination to forage to the ends of the earth if necessary in order to procure food. If the Park Service would expend a few dollars in bread for them it would doubtless be rewarded by a stay-at-home and more sociable and visible type of grizzly bear.

Stopping the shooting of grizzlies outside the Park is difficult, owing to the sentiment against bears and against game protection in the Rocky Mountain States, and owing more, perhaps, to the value of the hides and the sport to be found in shooting big game. Nevertheless, laws should be passed and enforced in all the states bordering on the Yellowstone Park prohibiting the shooting and trapping of these animals. Only such individuals as are proved to be cattle killers should be destroyed, and then only by special orders from the game warden, and by members of his own staff, not by the stockmen or others who may report the presence of marauding grizzlies. It is only occasionally that grizzlies become cattle killers, and such individuals should of course be prevented from doing damage. The indiscriminate slaughter of bears is stupid and brutal. At Canyon Hotel dump you may often see horses and grizzlies in the closest proximity to one another. The horses know that they are safe, or they would not approach a grizzly within fifty feet or less.

The grizzly bear has suffered more than any other large game animal of the United States. His natural range is now practically reduced to one small spot, the Yellowstone Park. He deserves our protection on account of his great scientific and educational interest, as well as because he is a thrilling feature of the original wilderness, and he should therefore be given at least as much consideration and protection as the other game animals. The intense popularity of the wild bears in the Yellowstone is undoubted proof of the high regard in which they are held by our people generally.

Photo by Edward A. Eichstaedt.

Fig. 58. The caretaker and one of his friends at Camp Roosevelt. These two have a mutual understanding and never take any undue advantage.

Photo by Edward A. Eichstaedt.

Fig. 59. Exploring the camp yard for possible tidbits. This cinnamon bear, with her litters of cubs, has been a leading attraction at Camp Roosevelt for several years.

Photo by Edward A. Eichstaedt.

Fig. 60. This scene may be witnessed any day at Camp Roosevelt where the wild bears may be observed and photographed at will, to the great delight of all visitors.

Photo by Edmund Heller.

Fig. 61. A black bear sitting astride a limb in a grotesquely man-like fashion,— not a common proceeding. Nothing is more fascinating than the bears' droll antics.

Grizzlies are usually pictured by writers as ferocious, solitary brutes, "carrying a chip about on their shoulders" wherever they go. Such statements are due to defective knowledge and false invention. Any person who has read James Capen Adams' account (cf. *The Adventures of James Capen Adams, Mountaineer and Grizzly Bear Hunter of California*, by Theo. H. Hittell, 1911) of the two grizzly bears, a male and a female, which he trained to accompany him in the hunting field, to carry packs, to be as docile as dogs, is furnished with a truer picture of the grizzly's character originally than that to be obtained in our modern books of hunting lore which paint this animal as extremely ferocious and dangerous in order to magnify the hunter's bravery in encountering him. He is no more dangerous than man's persecution compels him to be. But this does not mean that in his present state of mind this shy and wary giant is to be trifled with, or that the Park visitor can attempt any advances with impunity. The grizzly must be left severely alone, if he is to be saved as a species, and if he is to remain most useful as a type of primitive wilderness life.

In regions where the grizzly is hunted he may frequently travel alone, but the grizzlies in the Yellowstone appear to live in families (see pl. 26) for several years at a time, and are seldom solitary. That they live together as a rule and are sociable, may be considered a natural characteristic. Some of the old males may lead a solitary, cantankerous life, but such are the exception. "The Galloping Six," who have passed into Park history and legend, illustrate the grizzly's sociability. These six bears are said to have been adults of average size who were always seen together. They perhaps represented two families of young, three being the normal number in a litter. The Galloping Six were seen associated together in the Park for several years and the various thefts of food they committed are well remembered by the rangers.

My introduction to the Park grizzlies occurred on my first visit to the Canyon on August 26. I visited the Hotel garbage dump at sunset and watched with the waiting crowd of hushed and expectant tourists under the guardianship of Ranger Woodring. Just as it was growing almost too dark to see, the forms of two grizzlies came galloping out of the shadows of the pines and across the open meadow to the feast. Several black bears which had possession at the time discreetly vanished. The two grizzlies never faltered, but came running up the hill and hurriedly sought out the food possibilities. A few moments later another pair of grizzlies appeared, coming from the same direction as the first two. These came on at a gallop and as they neared their fellows the two first-comers gave way a little, while the strangers sought out a satisfactory dining place for themselves. Soon a third pair of grizzlies appeared, galloping toward their feeding brethren from the same direction. At sight of these last two the four that were feeding ceased and stood back, allowing the newcomers to approach and choose an eating place. Then all six settled down to sorting over the garbage peacefully together. This procedure was evidently grizzly etiquette. The six animals were adults and of equal size, and were easily distinguishable from the black bears even in the dim light by their high shoulders or "humps" and their saddle-shaped backs. We waited a quarter of an hour longer, whispering our remarks to one another so as not to disturb the shadowy monsters scarcely two hundred feet away. No more grizzlies came, and darkness settled down on the silent landscape.

A few nights afterward I saw ten grizzlies come to the same dump. One old grizzly with three cubs, this year's litter, came early just as the sun had sunk behind the dark pine-clad plateau. She approached slowly, being a cautious mother with a large family to fend for. She preceded her cubs a few yards and ascended the refuse dump. Later, the young ones were allowed to come up. Soon, however, her peace was broken by the appearance of the six grizzlies seen the night before, who came trotting along quite unconcerned. The mother moved away hurriedly with her cubs and gazed warily at the six as they nosed about among the tin cans. The babies stood up on their hind legs and stretched their wee necks to have a look at their big brothers. Finally, the mother made the cubs stop where they were while she went forward to feed and mingle with the six grizzlies now in possession of the dump. The young ones were well trained and sat patiently waiting in silence. As grizzly bear cubs do not usually climb trees they have little defense against members of their own species except by running. They are always in greater danger when they break parental discipline than are black bear cubs who can more readily climb to safety. On several other occasions I watched the grizzlies come to the dump, but never saw them solitary.

The Yellowstone Park staff should guard their grizzly bears as their most precious possession and should not allow any to be taken from the Park for any purpose, under any pretext. No museum should be allowed to kill specimens for scientific or exhibi-

Photo by Edward R. Warren.

Fig. 62. A tired cub resting high up in a Douglas fir, while its mother forages below. Black bear cubs always scamper up the nearest tree at the least sign of danger, or at a signal from the mother.

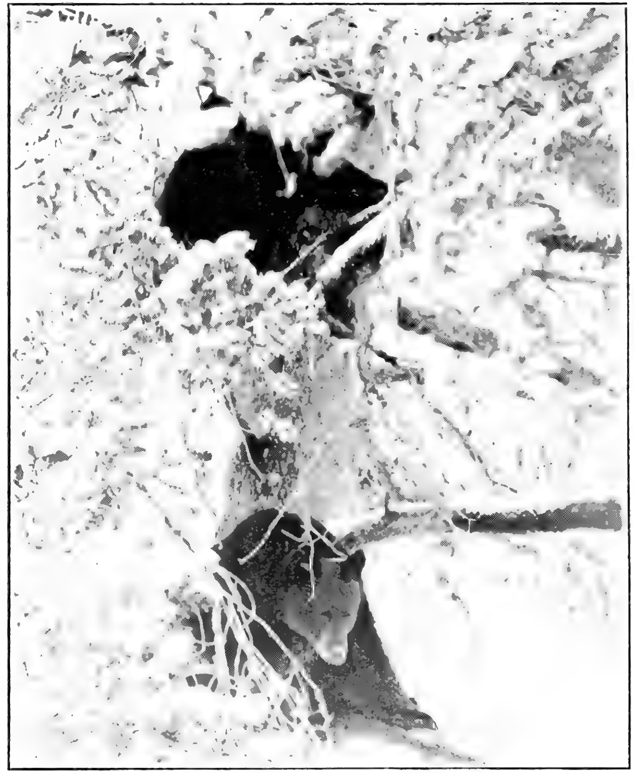

Photo by Edmund Heller.

Fig. 63. Seeking shelter in a pine tree during a September snowstorm. Two adult bears at peace in the same tree is unusual, except in an emergency.

Photo by Edmund Heller.

Fig. 64. A bull elk during the rutting season of late October, ranging in the sagebrush of Swan Lake Flat.

Photo by Edmund Heller.

Fig. 65. A bull elk with fully developed antlers in October among the aspen groves of the Lamar Valley.

tion purposes, nor should any zoological garden be allowed to trap breeding females for stocking its dens. Every effort should be made by the staff to preserve the few grizzlies still remaining in the Park and to encourage them to live wholly within the Park and rear their offspring there. At the same time we should try to secure their protection in all the surrounding National Forests. Under present conditions they are in danger of sudden extermination. Last season, grizzlies came to only two out of the ten or eleven garbage dumps where black bears feed regularly, namely at Canyon and Lake Hotels, and the rangers who had these two dumps in charge reported in all only some 25 individuals during the whole season as visiting the dumps. Under these circumstances it is surely high time that the Park Service grant no more permits for the slaughter or capture of grizzlies. An effort should at once be made by the management to guard them most strictly until they become more generally distributed over the reserved area, so that they can daily visit most of the garbage dumps and be seen by a majority of the tourists instead of by only a few. Some day we may thus have a surplus of grizzlies in the Yellowstone Park, and when that happy time arrives a few of the bears may be legitimately captured for zoological gardens and museums.

BLACK, BROWN OR CINNAMON BEAR

Ursus americanus Pallas

There is no more appealing animal in the Park than the black bear. His is a popularity based on his friendship for man, and is well deserved. His gentleness and confidence in the people he meets with (see figs. 56, 57) and his diurnal habits and love of camps and hotels, makes him an easily found and observed animal. The black bear is the only large mammal that is seen and photographed by many visitors, for the deer and elk though more abundant are timid forest folk, and the grizzly is a nocturnal rambler and very seldom seen in broad daylight. The most marvelous bit of animal psychology I noted in Yellowstone Park was the intelligence displayed by the black bears in their not unfriendly advances toward man and the sagacious manner in which they accept his profferings of food (fig. 58). They are better mannered and more reserved in the presence of food than even that noble animal the dog. The display of restraint necessary to keep in check a hunger-born instinct to rob and take by force the food offered them at arm's length by weak, frail humanity is really remarkable in a wild, free-wandering bear! The black bear who has tamed himself deserves all the encouragement we can give him as well as our friendship and protection. The Park management is protecting the black bears against the tourist, as they are really too friendly and confiding toward undisciplined, thoughtless humans, who are sometimes tempted to tease and play practical jokes on good-natured bears and thus irritate them to the point of committing murder. *It should be borne in mind that bears are wild animals of uncertain mood and can not be safely fed out of hand by the visitor.* To quote the emphatic warning of Park Naturalist Skinner: "LEAVE 'EM ALONE!" Some tourist is sure to unwittingly tantalize some bear by displaying food to him and keeping it just out of his reach. A savage attack by the bear is often the dire result.

Your own pet dog, when feeding, would probably not permit such liberties; why should a wild bear? No zoological garden permits visitors to feed or tease its animals, for the best of reasons. Moreover, it is their very wildness that gives the bears their charm, and nothing would be less desirable in a wilderness park than to domesticate its wild denizens. The Park management has stationed rangers at all the garbage dumps to see that this rule against tourists feeding or annoying the bears is obeyed.

The black bears deserve a thousandfold the protection and the food that is given them, but they are still far less numerous than they should be, and are to be seen with certainty at only a few places along the loop highway. But, as indicated in our discussion of the grizzly, only an enlarging of the Park, or thoroughgoing protection in the surrounding National Forests, will result in a permanent increase in the number of bears. At Upper Geyser Basin, the Lake, and the Grand Canyon, they frequent the hotel garbage dumps (figs. 54, 55) together with the grizzlies. But at Camp Roosevelt they may be observed and photographed at close range during any hour of the day (fig. 60), and their droll antics and fascinating ways are a continual delight to the onlooker.

The black, brown and "cinnamon" bears—all merely color phases of the same species—are remarkable tree climbers (figs. 61–63) and the dense conifer forests are their ever-ready refuge. It is most amusing to watch a pair of cubs go scampering up a tall fir at a quiet signal from the mother, or when thrown into a temporary fright by some imaginary danger. Plate 25 represents a typical family of black bears in their Yellowstone home. In the vicinity of Camp Roosevelt their well-worn trails and the marks of their

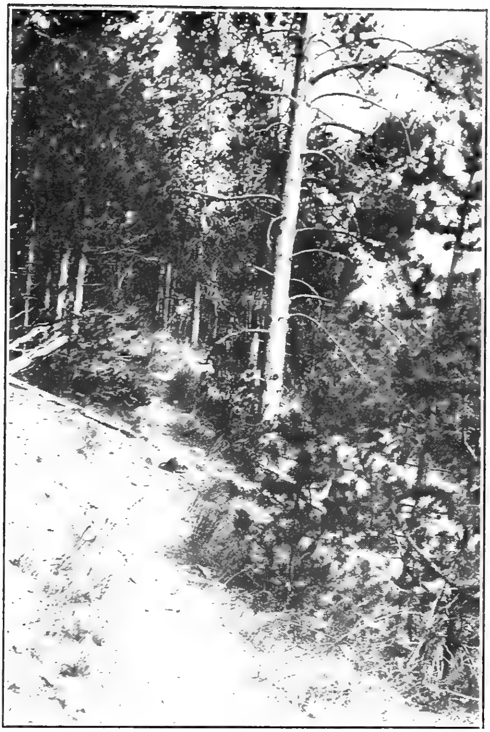

Photo by Edward R. Warren.

Fig. 66. An elk trail through the lodgepole pine forest on a ridge beside Lost Creek. Such trails often parallel the deep ravines, crossing at favorable points.

Photo by Edmund Heller.

Fig. 67. A group of elk cows and their calves in aspen woods near Mammoth Hot Springs in winter.

Photo by Edmund Heller.

Fig. 68. A band of cow elk in the snows of late November at Mammoth. This open cedar grove was severely browsed by elk during a starvation period, the winter of 1919–1920.

Photo by Edmund Heller.

Fig. 69. An elk herd (males and females) in the Upper Gardiner Valley in late November.

powerful claws on the tree-trunks are to be found all about. The presence of such universally interesting animals should by all means be encouraged and they should be allowed to become more plentiful, but kept in their wholly wild and natural state.

There are in Yellowstone Park probably less than 150 black bears. The former Park Naturalist, Mr. M. P. Skinner, estimates about 125, and my observations in 1921 would lead me to consider this figure a fair one. I did not meet with more than thirty different individual bears in three months' study and search. The black bears fail to increase in numbers for very much the same reason that the grizzlies do. Special feeding in the late autumn, after the hotels and camps close, would keep them inside the Park at a time of year when they must eat heartily and store up fat for their long hibernation of four or five months of winter. They cannot hibernate successfully unless in fat condition and they should not be forced by lack of food to hibernate outside the Park. The killing of black bears in states bordering the Park should be absolutely prohibited, as they almost never become cattle killers (though they occasionally kill sheep and pigs) or interfere seriously with the sort of agriculture practiced by the farmers of the Rocky Mountain states. Yellowstone Park unfortunately produces very little bear food except grass and the roots and bulbs of a few herbs, and in the lower valleys mice, ground squirrels, and other small mammals. Berries are far from abundant and there are no mast or nut producing trees or bushes in the Park from which bears can secure much food. In Yellowstone Park the hotels and camps close by September 20, thus suddenly cutting off their artificial food supply. This is a very serious and unpractical joke to play on the gentle and confiding bears, who have been led to expect their regular daily rations. Thereupon Bruin becomes a burglar (see fig. 53), or failing in his raids for food he often leaves the Park on a foraging expedition from which he probably will never return. We should, moreover, not forget that well-fed bears are more likely to be well-behaved bears. Their house-breaking depredations in the Park are all committed in the autumn after the hotels have closed and the bears are left foodless. A few hundred dollars spent annually by the Park Service for suitable bear food would keep the creatures at home during the critical period, and also restore their confidence in the Park as a land of plenty and a safe haven at all seasons.

GRAY WOLF

Canis mexicanus nubilus Say

Does not the wolf also deserve a place in the Yellowstone Park? He is the noble or ignoble hero of much of our literature. Who would not give a year of his life to see a wild wolf or a whole pack of wolves trailing down an elk or deer? The carnivorous animals that kill their prey are always our choice in story and in the hunting field. If they were not killers that show pluck and courage we should not admire them. But since we admire the wolf and are thrilled by his exploits why not tolerate him, at least in our wilderness parks? Great elk herds are not conducive to a balanced piece of nature without the wolf to add fire and alertness to their lives. Protected like cattle the elk become like cattle. Herds of hoofed game, without the presence of a few carnivorous beasts whom they fear, lose much of their character and interest. Should we not be glad to pay for a wolf's mere presence and his "demoniac" howl with one or two elk a month as food?

There are but few wolves now remaining in the Yellowstone; they are almost exterminated in a land where at least their voice should be heard. I was saddened last year in Yellowstone Park not to hear a wolf howl. Northern Michigan and Wisconsin outdo the Yellowstone as a wilderness in which the howl of the wolf is still a woodland melody. In that land of forest and swamps he howls nightly. He lives afar from the ranch of the stockman, and no lumberman or forest owner fears him or wishes to accomplish his extermination. I hope some day to see a pack of wolves in full cry after their hoofed quarry and see with my own eyes how they pull down their game. I do not advocate the support of many wolves in our parks, but a few would help secure a condition of balance amid our wild life and maintain the alertness of the game animals.

MOUNTAIN COYOTE

Canis lestes Merriam

A very much maligned animal in the Yellowstone Park is the coyote. Here he dwells in the one place where protection should be afforded him, in a Park where all the hoofed denizens get a fairly square deal, a chance to lead their normal lives to a normal finish. What a National Park should in general aim to be is a balanced piece of nature, where we see nature as it was before the coming

Photo by Edmund Heller.

Fig. 70. A band of cow elk in the Gardiner Valley in early winter. The characteristic gait is a rapid trot, the muzzle being held high.

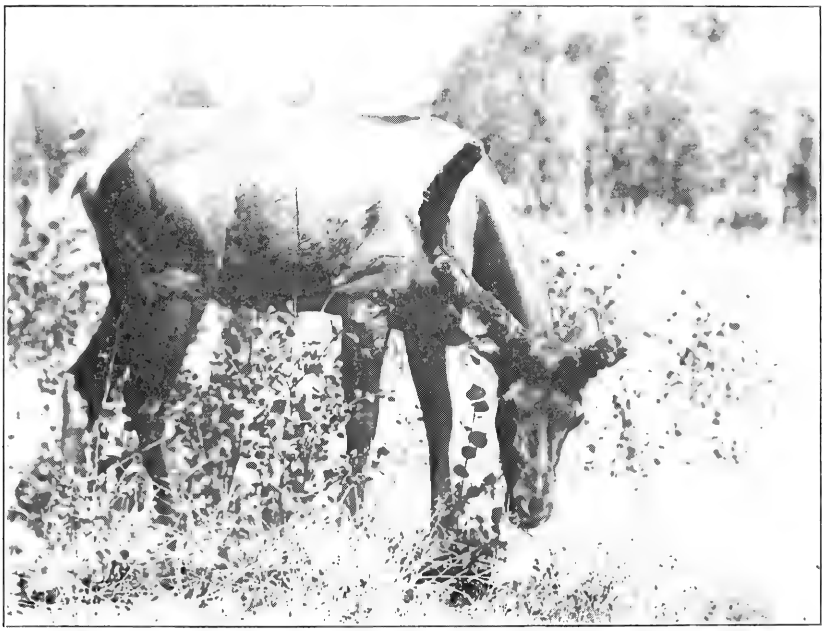

Photo by Edward R. Warren.

Fig. 71. "Billy," the gelded elk that for several years frequented Camp Roosevelt and the Lamar Valley in summer, migrating to Mammoth in winter. The abnormal antlers were soft, and were never shed; one had been accidentally broken.

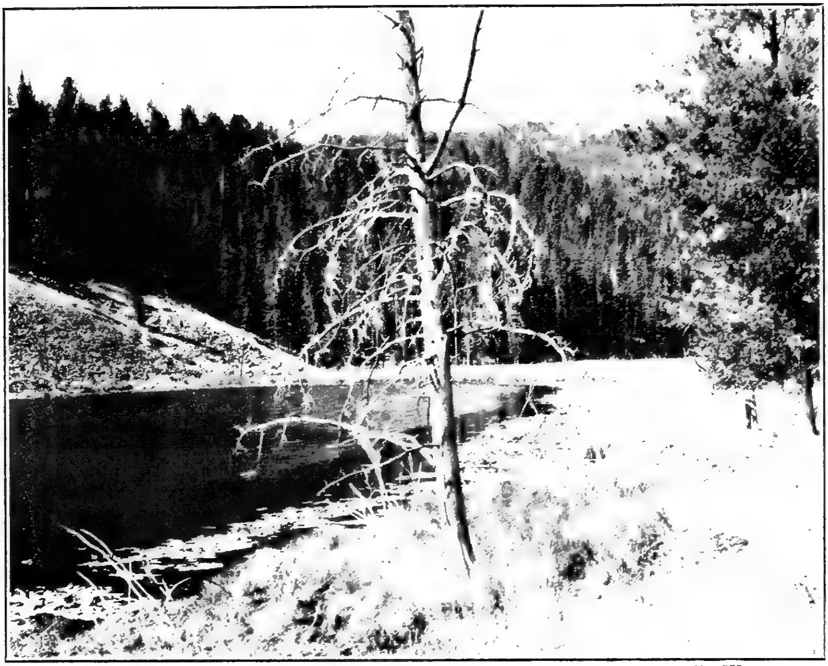

Photo by Edward R. Warren.

Fig. 72. Lost Lake, near Camp Roosevelt, now a favorite haunt of moose. The lake is bordered with a zone of yellow water lilies. A beaver lodge may be seen at the right.

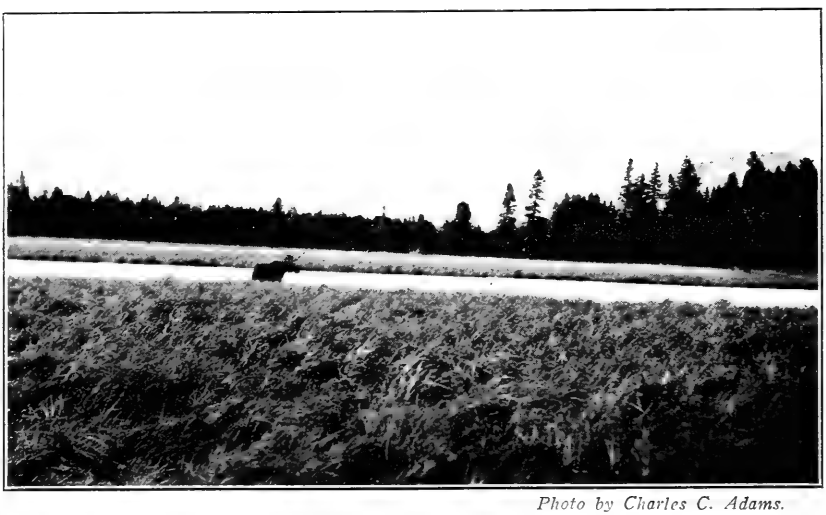

Photo by Charles C. Adams.

Fig. 73. A bull moose feeding in the outlet creek of Bridger Lake, near the headwaters of the Upper Yellowstone and just outside the present Park boundary. Note the long bell or dewlap hanging from the throat.

of the white man, with no foreign species of animals inserted and no native ones excluded. How can we have a balanced Yellowstone Park with the coyotes excluded? The coyote may occasionally kill a fawn, but only rarely. He is really a mouse catcher and you may see him daily in the Park meadows searching for mice. He is our weirdest carnivorous mammal and deserves a place in our parks and our hearts. Anyone who has heard the song of a coyote, that uncanny medley of diabolic sounds, realizes that he is a most unusual animal, a serenader of really great charm and baffling melody. One coyote sounds like a whole pack, either of coyotes or of evil spirits, according to your mood. Ernest Thompson Seton has justly sung the coyote's praise, and there is no man of our generation whose sentiment in natural history has received wider acceptance.

The coyote is shot on sight in the Yellowstone because the Park officials have not yet conceived the idea of *balance* in nature. They have striven to have a park filled with elk and other hoofed game to the exclusion of other interesting animals, or at least they have placed emphasis on various species as worthy of preservation and condemned or looked indifferently on others. Any coyote caught killing fawns or lambs should, it is true, be separated from his spirit at the point of a bullet as an undesirable denizen. The Park rangers love to have some live object on which to try their markmanship and the coyote is their legitimate prey under the present rules. I do not blame the rangers. They have the hunter's instincts strongly developed and their love for animal life was acquired or developed in the hunting field, where the prevailing idea has been to save only the hoofed game, and solely for the hunter's own killing and use.

As a finale I wish to add that the song of the coyote is more welcome to me and dearer to my heart as a real expression of wild life than the songs of most birds. While in the Yellowstone Park I heard several coyotes sing, and the voice of one I listened to in a canyon was much amplified in volume and positively startling. As they sing, their sharp little muzzles are pointed straight up heavenward in the most approved ecclesiastical way. Any normal mouse-hunting coyote (an animal with the voice of a devil as well as that of a bird) should receive the protection and encouragement of everyone.

COUGAR OR MOUNTAIN LION

Felis concolor hippolestes Merriam

How can we sympathize with an animal which is by habit stealthy, exceedingly crafty but cowardly, usually voiceless, and which preys wholly on game animals for its livelihood? We could forgive it for feeding on game, because it is a carnivore, but how can we be friendly toward an animal that can neither be seen nor heard? As far as the Yellowstone Park is concerned, some people ardently interested in wild life may feel that the cougar might well be dispensed with, as this is a region where he cannot actually be observed under natural conditions. But his tracks at least may be seen occasionally in the snows of winter, and while there are ordinarily no great thrills to be gotten out of observing spoor, the mere fact that such a great beast, the largest of our cats and self-sufficient in the face of all man's hunting arts, exists unseen in our Parks, adds a glamour that pleases the imagination of all who love to camp or follow the wilderness trails. A few cougars still exist in Yellowstone Park and their absolute extermination may perhaps never be permitted; nor need this be regretted, for we do not yet know how valuable to science and interesting to the public any species of wild animal may prove to be. And as any form of wild life once extirpated can never be brought back, we should not deliberately press a campaign of utter extermination.

There is at least one place in the United States where the cougar should be treated as a sporting animal and not poisoned as "vermin." On the rim of the Grand Canyon in Arizona he is hunted successfully with hounds by sportsmen. The cougar in that region furnishes some of the grandest thrills to be had in the hunting field in America. He, himself, is never dangerous, but following him on the rim of those dizzy cliffs which mark the mile-deep canyon requires courage and steady nerves. The cougar often takes refuge below the rim of the canyon and the sportsmen who follow him must dismount and descend the cliffs on foot and rout him out of his hiding place. Such hunts take place amid the grandest canyon scenery in the world and on a pine-forested plateau ranging from 6000 to 9000 feet in altitude.

Mule deer are abundant in the forest bordering the canyon, and the cougars seem by no means able to make any diminution in their rapidly increasing numbers. Sportsmen would be glad to see the Government desist from attempting wholesale destruction of the cougars and save them for the chase. Many come annually to hunt mountain lions in this wonderful region of canyons. Resident guides like Jim Owen, who piloted Colonel Roosevelt to the lairs of the cougars on several of the Colonel's hunts, have trained hounds for the purpose of assisting and encouraging such sport. Why should the Government spend its money in destroying a noble sport by exterminating an animal that is economically harmless in a region like the Grand Canyon where stock raising is not now permitted

Photo by George Shiras, 3rd.

Fig. 74. A calf moose feeding on aquatic plants in Southeast Arm, Yellowstone Lake.

Photo by George Shiras, 3rd.

Fig. 75. A bull moose and two calves ranging along Trail Creek, Upper Yellowstone Valley. A characteristic moose habitat, with three zones of vegetation,— marsh grass, willow thickets, and dense spruce forest.

Photo by George Shiras, 3rd.

Fig. 76. A cow moose and twin calves, on the south shore of Yellowstone Lake.

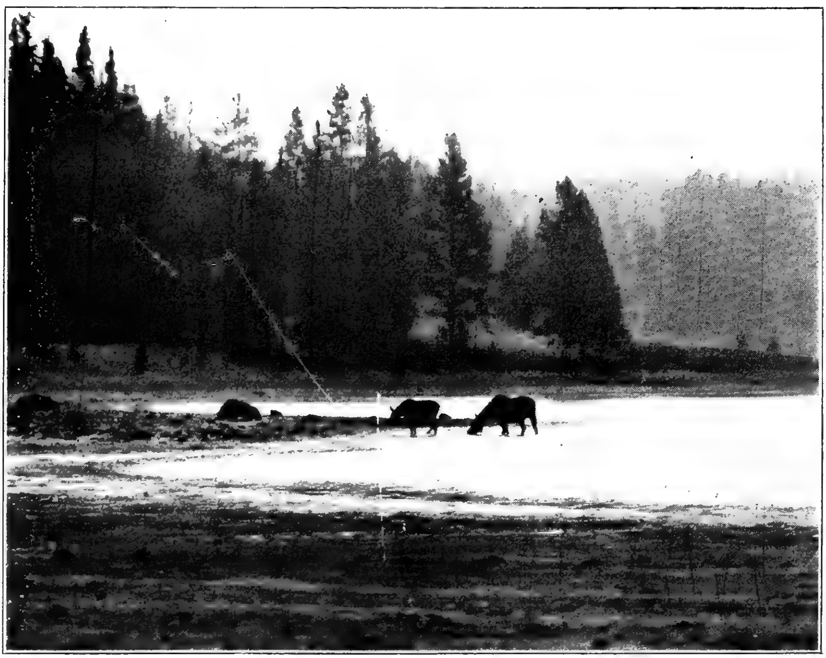

Photo by George Shiras, 3rd.

Fig. 77. A cow moose and calf feeding on water plants, Upper Yellowstone Valley. Lodgepole pine forest in background.

on the commercial scale formerly allowed? Many outdoor enthusiasts have enjoyed cougar hunts on the rim of the Grand Canyon and our hunting literature is filled with tales of their adventures. Nor is it always the chase that ends in a killing that is most memorable. When the cougar has been treed or brought to bay, the camera sportsman is sure to get some thrilling photographs, the best sort of trophy of his adventure and one that does not tend to deprive others of like opportunities.

ELK OR WAPITI

Cervus canadensis Erxleben

More care is lavished annually on the great elk herds of Yellowstone Park than on any of the other big game species. The Park management takes a laudable pride in having maintained large numbers of the elk in the face of very great difficulties. The story of the rangers' desperate struggle year after year to save the elk from the hunters lining the boundary and eager for slaughter, is vividly described in Hal Evarts' *Passing of the Old West* (1921). The results of the Park protection policy are encouraging, as these animals still far outnumber all the other species of big game combined. With the proposed southward enlargement of the Park, which it is hoped Congress will provide for in the very near future, the safety of at least the southern herd will be assured for all time.

The summer tourist notices elk trails everywhere in the forests and on the open hillsides, often deeply worn by thousands of hoofs along the main migration routes (fig. 66); but he seldom sees the animals themselves, as they are ranging on the higher slopes at that season. If he were to visit the Park in late autumn, however, he would find the valleys dotted with many hundreds of them. In severe winters they are fed on hay cut and stacked in these valleys the previous summer. The wapiti do not thrive on willow browse like the moose, but when hard pressed in winter they commonly resort to the aspen woods (fig. 67) where they gnaw the green bark of the trunks to eke out a scanty fare.

To me, the finest spectacle in Yellowstone Park is that of the rival elk bulls bugling and fighting in the autumn for the possession of their harems. The heavily antlered males are exceedingly noble in carriage, especially when traveling at speed, muzzle pointing straight forward and the great antlers lying back along the sides. Their characteristic gait is a rapid trot (fig. 70).

Early snows in the Park are a source of great danger to the elk herds, which then wander past the boundaries in spite of the patrols of rangers desperately striving to keep them in. Once outside the Park during the open hunting season the elk are shot by the local sportsmen in great numbers. The year 1919 was one of the most disastrous. Following a year of drought and scant forage, early snow-storms that autumn drove the elk out of the Park, and some 10,000 of them were killed. The ranger force could do nothing to prevent the slaughter of elk that had escaped into the territory of the adjacent states, even within the National Forests. They viewed this most recent slaughter with great sadness and dismay, for they who should have the power to protect their herds in fall as they had in summer, no matter where they strayed, were legally helpless. The Park officials had feared just such a catastrophe and had warned against it for years. In his annual report, prepared in the summer of 1919, only a few months before the blow fell, Superintendent Albright stated the critical nature of the situation as follows:

"Every person in this country who is interested in the conservation of wild life, who wants to see a supply of big game sustained, who wants Yellowstone National Park to hold its prestige as a great natural preserve, should give attention to the problem confronting us at the present time in caring for the elk. The time is coming when a terrible, long, cold winter is going to kill the Yellowstone elk herds if existing conditions outside the Park are maintained. That time may be the coming winter; however, it may be a winter of ten years hence. No one can say when this calamity will strike us, but those of us who know conditions about this Park realize that the extinction of the elk is inevitable unless these conditions are changed."

Under state game laws permitting the shooting of elk in November, a series of early winters would result in cutting the elk herds down to but a few bands. No elk shooting whatever should be allowed within the area surrounding Yellowstone Park where these animals winter habitually or normally. Failing such legislation, the open season should be shortened and placed at an earlier date, so that early winters will not force the elk out of the Park at a time when hunters are allowed to shoot them. Wyoming has befriended the elk and passed laws protecting them, and has given them some security in their winter home in Jackson's Hole. The Montana law was fortunately considerably ameliorated following 1919, but the herds are still in great danger.

This year, 1921, the elk remained on their summer range in the high forests within the Park until October 24. From that date herds were to be seen continually in the region about Fawn Creek and

Photo by Edmund Heller.

Fig. 78. Antlers from a "winter-killed" moose on the Upper Yellowstone. The prongs have been gnawed off by porcupines or other rodents.

Photo by Edmund Heller.

Fig. 79. A mule deer buck and his does resting on the "parade ground" at Mammoth Hot Springs. An autumn scene.

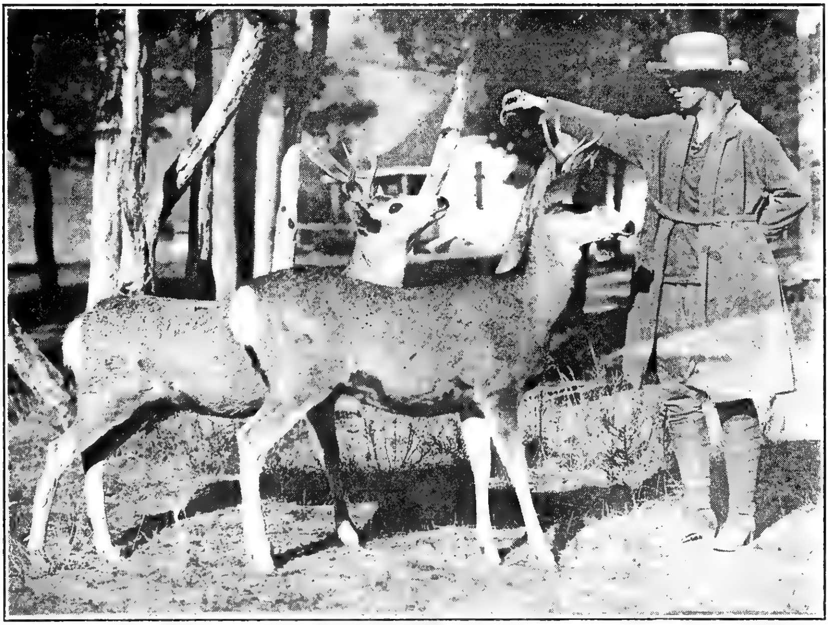

Photo by Edmund Heller.

Fig. 80. A pair of mule deer in autumn at Mammoth Hot Springs. Mule deer quickly lose their shyness on the approach of winter.

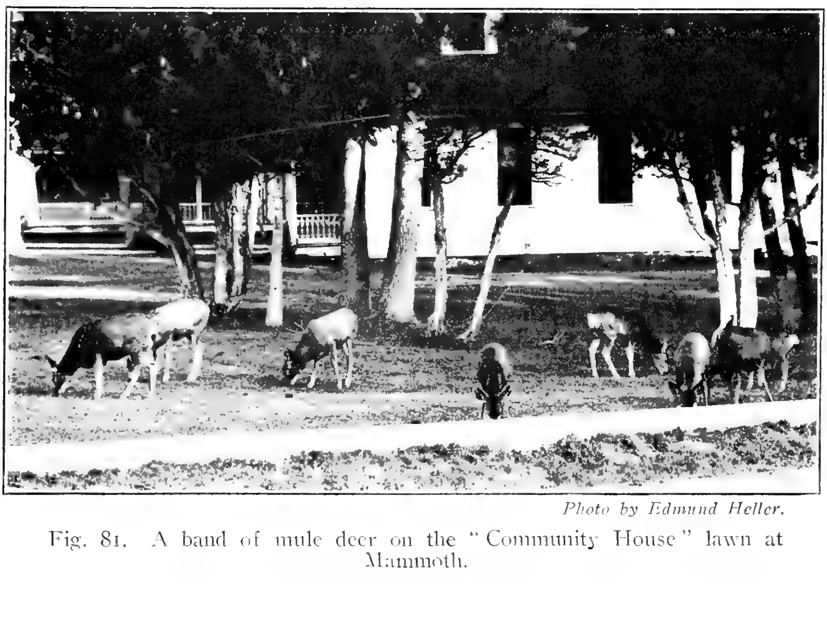

Photo by Edmund Heller.

Fig. 81. A band of mule deer on the "Community House" lawn at Mammoth.

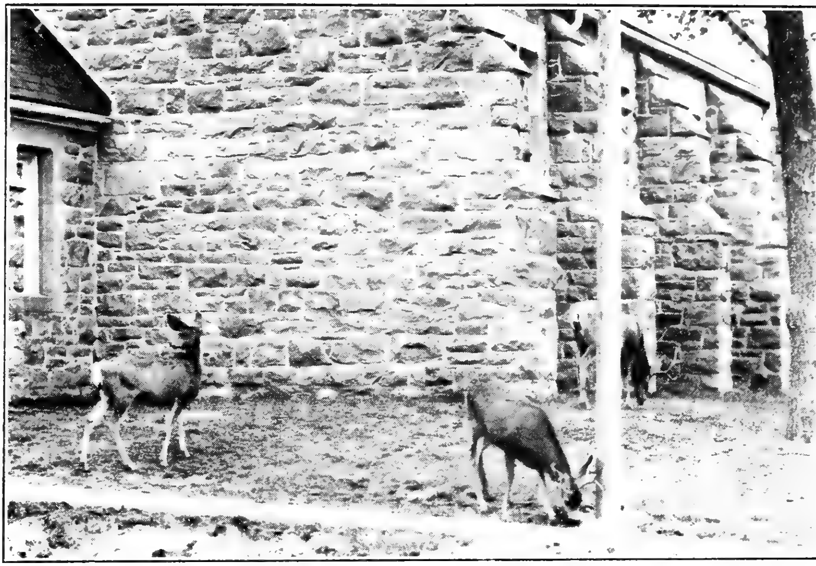

Photo by Edmund Heller.

Fig. 82. "In sanctuary." Mule deer at Mammoth Hot Springs chapel.

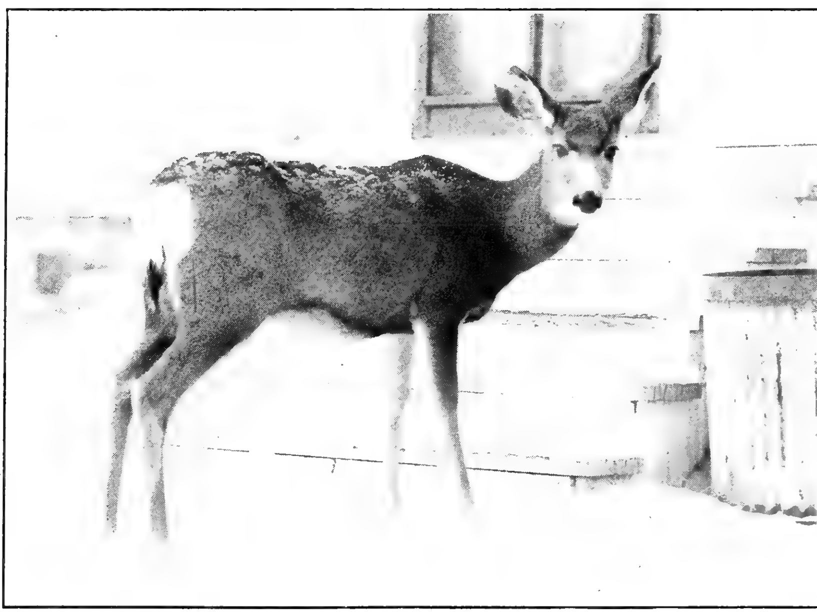

Photo by Edmund Heller.

Fig. 83. "Old Molly," a pensioner in winter at the kitchen doors of the Mammoth Hot Springs community.

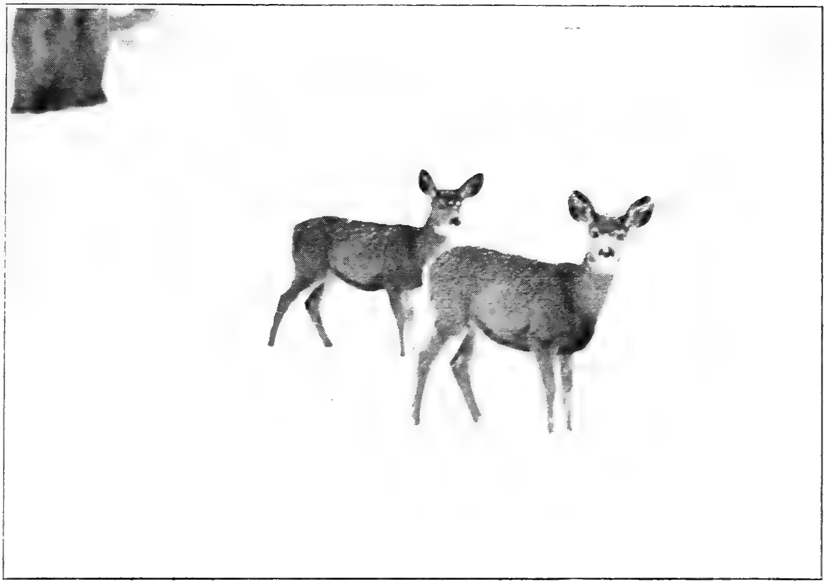

Photo by Edmund Heller.

Fig. 84. Twin mule deer fawns at Mammoth, experiencing their first snowstorm.

Photo by Edmund Heller.

Fig. 85. A mule deer stag in late November. The "last look," a deer habit which gives the sportsman a standing shot and would be fatal beyond the Park boundary. Note the double-branched antlers and white rump patch,— diagnostic marks of this species.

Snow Pass. They grew daily more abundant and the bugling of the bulls filled every valley. By November 20 they appeared on the flats bordering the Gardiner River at Mammoth, where I saw numerous bands (figs. 68-70), and sometimes as many as a hundred individuals in a day. This locality is only four miles from the northern boundary of the Park. The autumn of 1921 was unusually mild and open, and the first permanent snow came about November 18. The danger of elk leaving the Park in even mild autumns is considerable, as was shown by their close approach to the north line at this season.

At Camp Roosevelt, so remarkably well located for the study of wild life, the summer visitor until recently was likely to see "Billy," the interesting gelding elk, the only actually "tame" big game animal in the Park (fig. 71). He roamed up and down the Lamar Valley in summer, but spent much of his time at Camp Roosevelt, where although mischievous, he was a great favorite. In autumn he migrated to Mammoth Hot Springs, but never consorted with other members of his species. (See also *Journal of Mammalogy,* Vol. 4, 1923, p. 252, for a brief history and photographs of this elk, by M. P. Skinner.)

YELLOWSTONE MOOSE

Alces americanus shirasi Nelson

The moose are perhaps doing better than any other of the large mammals. Not only are they holding their own, but they are apparently increasing in numbers and enlarging their range. From the extreme upper Yellowstone River and Lake region which is their chief stronghold (figs. 73–77), they have been spreading out gradually during the past twenty years. Now they are to be found on Fawn Creek in the Gallatin Range; in the Bechler River region,—part of the Snake River drainage; on Upper Slough Creek, tributary to the Lamar River; scattered through the Blacktail Deer Creek and Camp Roosevelt region (fig. 72); and in other sections where suitable swampy areas occur. I observed a number of moose this year (1921) while accompanying Secretary of the Interior Fall's party on a journey along the Upper Yellowstone River to the southern boundary of the Park (fig. 47). In this region we saw in two days' travel over the regular trail from the Lake to the boundary, fifteen moose the first afternoon and at least four the following day. The moose showed little fear of us; in fact they seemed to have as much confidence in humanity as range cattle. The sight of these great deer standing solitary on the edge of the forest or feeding in family parties in the willow thickets bordering the Yellowstone River enthralled us, and it made our ride that first day an unforgetable adventure. To even come upon one of their heavy antlers while riding the remote wilderness trails gives zest to the trip. The skeletons of winter-killed moose are occasionally to be seen. Figure 78 shows a ranger bringing in a skull and attached antlers of a winter-killed specimen. One frequently finds antlers of moose, elk and deer that have been similarly gnawed by porcupines, pine squirrels or other rodents.

A great step forward in game conservation will have been made if the Park Service is given charge of the extreme upper headwaters of the Yellowstone River, which are an important part of the moose range and unquestionably belong to the Park topographically. The explorations and the photographic studies of moose made by Mr. George Shiras, 3rd, in this general region in 1908 to 1910 (see *National Geographic Magazine*, July, 1913, pp. 808–834) indicate the necessity of eventually adding the Upper Yellowstone basin to the Park to safeguard this superb mountain species. In 1921, Wyoming permitted fifty moose to be killed in this nook of territory, and these fifty moose were virtually taken from Yellowstone Park. They were killed for no legitimate purpose but to satisfy a few venison-hungry cattlemen. There was no sport concerned in shooting them, for they were as tame as cattle. Such moose should be fully protected and allowed to live their natural lives. They are fair game for the adventurous summer explorer with his camera, and should furnish keen pleasure to hundreds of people annually who travel thousands of miles and spend much money in this region to see a primeval wilderness, rather than fall victims to a few local ranchmen. In 1922 Wyoming again permitted fifty bull moose to be killed, with the result that their cows went unmated and produced no calves, as the moose is not polygamous in habit.

MULE DEER

Odocoileus hemionus (Rafinesque)

From the standpoint of the Park visitors mule deer are a feature chiefly of Mammoth Hot Springs. In winter they are absent from nearly all the Park area except the northernmost district which has the lowest valleys; though Mr. Skinner informs me that a few bands winter between the geyser basins and elsewhere on the Park plateau. There are always a few to be observed in the vicinity of Camp Roosevelt and in the country lying between there and Mammoth, and tourists sometimes see them in the edges of the forest along the

Photo by Edmund Heller.

Fig. 86. A mule deer in the rutting season during October.

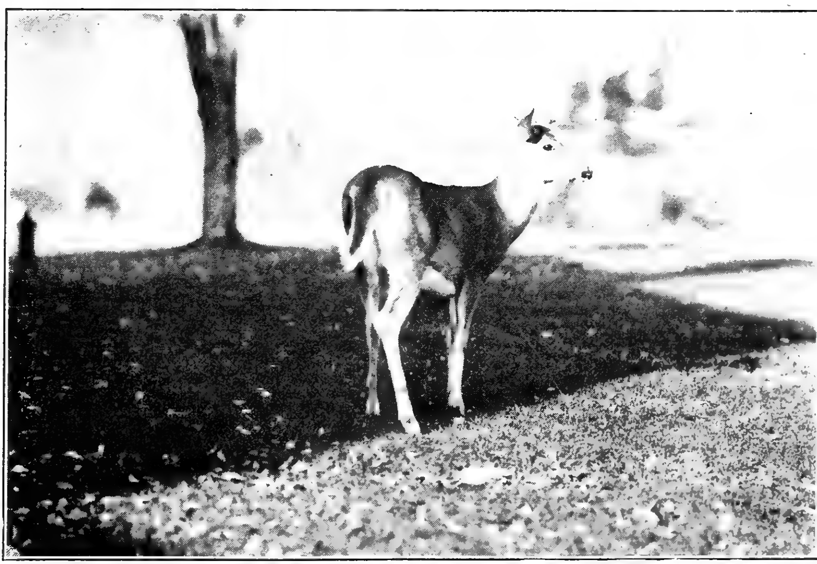

Photo by Hilda Hempl Heller.

Fig. 87. A white-tail buck, at Mammoth. Unlike the mule deer it has single-beam antlers and a broad tail. White-tailed deer are shy even in winter, and only a few are now left in the Park.

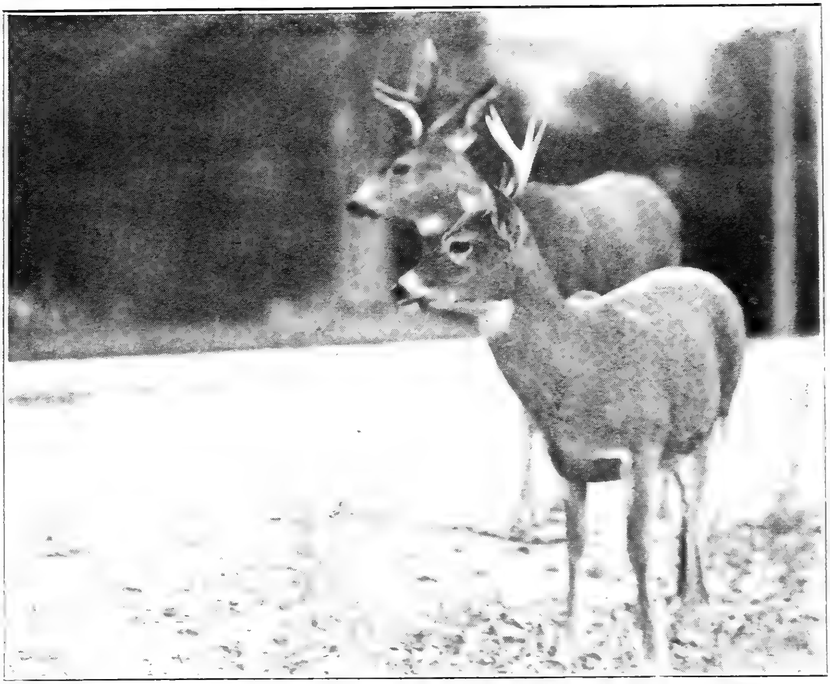

Photo by Edmund Heller.

Fig. 88. A white-tailed deer (in front) and a mule deer in company in the fall.

Photo by Edmund Heller.

Fig. 8[illegible]. [illegible] Note the absence of a white rump patch and the [illegible] of the white-tailed deer (at right), and the narrow, [illegible] roads throughout the Park. At Mammoth in the fall the mule deer reigns supreme. He and his family take possession of the deserted lawns and carefully crop the grass as short as any lawn mower could (figs. 81, 82). Deer are browsers, also, but to see a band of them at work on the lawns of Mammoth one would never suspect them of any food habit other than grazing.

About September 12 they began to appear on the hillsides near Mammoth either singly or in family parties. At this time they visited the lawns only at night, spending the daytime in the adjacent woods and pine forests. After the Park season closed, September 20, they grew bolder and visited the lawns during the day. Later they became actual residents and remained about the houses day and night. Often I saw them lying down at night on the lawns, sometimes actually in front of the doorsteps of the occupied houses of the Yellowstone Park staff.

When the permanent snows came in mid-November there were some fifty individuals about the houses and lawns of Mammoth village. Many of these deer were the offspring of such famous old beggars as "Ash Can Pete" and "Molly the First" (fig. 83), familiar to all the villagers in winter. The old bucks in mid-November carried fine large antlers (figs. 85, 86) and were then engaged in social pursuits, flirting and fighting. There was remarkably little fighting, however, so far as could be seen. Nearly every buck knew his place in the social scale, and the lesser bucks simply moved away, and kept out of range of the stronger when they appeared. Feeding bread, apples, and other food to deer by hand was a pleasant and usually a harmless pastime at Mammoth. Feeding several deer at once was slightly dangerous, owing to the possibility of one of them suddenly, in a fit of jealousy, striking out at another and at the donor with his fore feet.

The fawns are timid little sprites and retain the racial fear of man. They never show the confidence in him that is displayed by their parents, which forget their fears and feed freely from his hand with the coming of autumn. The mule deer are a pleasure to all the Park residents. During the long winter months they are daily visitors to the snow-bound community at Mammoth. The only other Park animals that approach the mule deer in popularity are the cub bears who entertain summer visitors with their droll antics. The mule deer appear to be safely holding their own in the Yellowstone Park; but we have learned that with every one of these big game species appearances are liable to be deceiving. Year by year they seem to be becoming gradually tamer until now they have reached a stage of semi-domestication which asserts itself chiefly in the winter season. Like the elk they are shy in summer, keeping out of sight in the forested areas, and are only occasionally seen by tourists. These two members of the deer family give the visitor in summer who would go in quest of them off the noisy highways plenty of exercise for the hunter's instincts and woodcraft. This condition of affairs, highly desirable in several ways, is ideal for the practice of trailing and wild life photography, and is being utilized as an educational feature for the boys who spend their summers camping in Yellowstone Park. *A National Park should never be made a zoological garden.* It should harbor only its own natural fauna in normal numbers and should be a sanctuary where the animals are to be sought rather than a place where they are on exhibition.

WHITE-TAILED DEER

Odocoileus virginianus macrourus (Rafinesque)

The graceful little white-tailed deer inhabit the country about Mammoth Hot Springs and elsewhere at the north end of the Park, in the valleys of the Gardiner and Yellowstone Rivers. They are the wood nymphs of the Yellowstone, gentle but timid (fig. 87), and show no such familiarity with man as their larger cousins the mule deer. Their tribe is not numerous, for apparently less than fifty live inside the Park. I saw only some fifteen individuals during two months' observation in the late autumn of 1921 at Mammoth, where one might find small family groups of these exquisite creatures about the lawns at dusk every evening. They were easily approached and gentle, but more nervous than mule deer and did not come to the kitchen doors to be fed as did many of the latter. In the daytime it was rare to see the females on the lawns. They remained hidden in grassy hillside nooks, while an occasional white-tail buck might be found associated with the mule deer about the human habitations (figs. 88, 89).

The winter in the Park is evidently too severe for the white-tail deer. When the landscape about Mammoth became white with snow, and winter really settled down to stay, they were no more to be seen, though ordinarily a few are observed throughout the winter. Evidently they moved down the valley of the lower Yellowstone where the climate is warmer, but unfortunately protection from hunters is much less or entirely wanting there. Doubtless it is the killing of the deer outside the Park that keeps their numbers at so low an

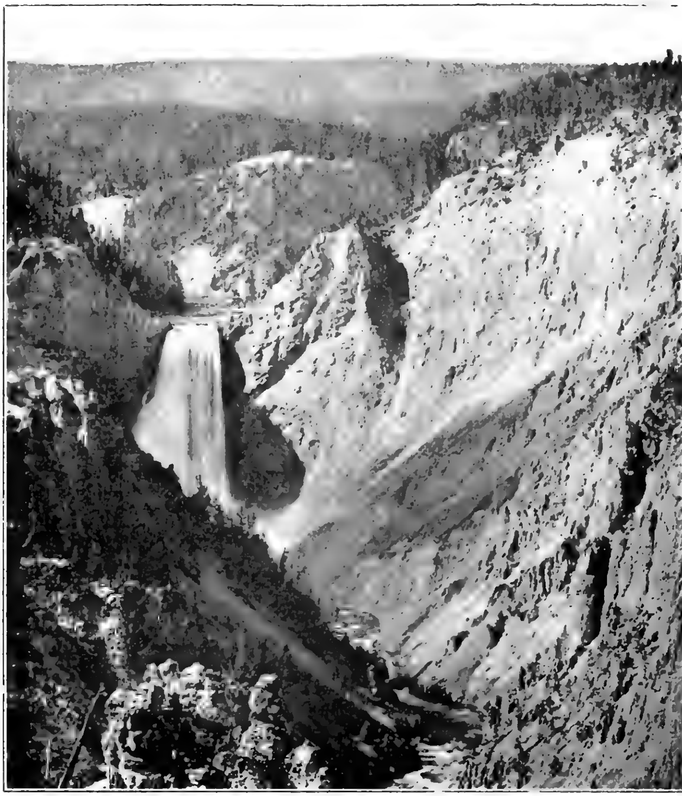

Photo by Edmund Heller.

Fig. 90. Grand Canyon of the Yellowstone, and Lower Fall, 308 feet high. Mountain sheep trails lead down the precipitous slopes to the river; and the dense lodgepole pine forests on the plateau are the summer home of the grizzly bear.

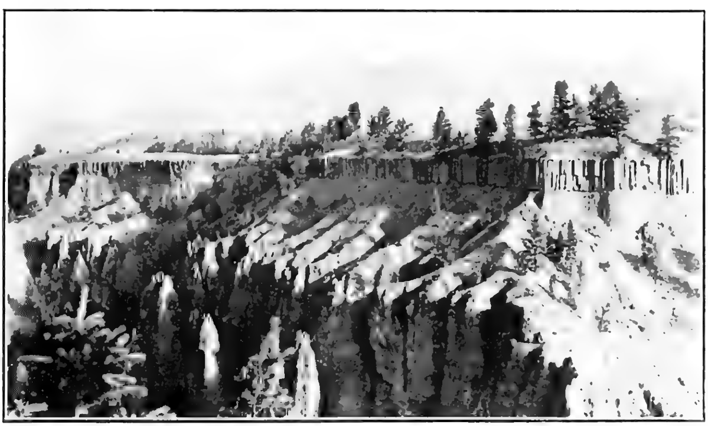

Photo by Edmund Heller.

Fig. 91. Lower end of the Grand Canyon, near Tower Fall. The canyon rim is one of the favorite winter homes of mountain sheep. This is where Roosevelt and Burroughs camped and watched them descend the cliffs 600 feet to the river, in April, 1903.

Photo by Edmund Heller.

Fig. 92. Bighorn sheep scenting danger. They may be seen occasionally from the touring busses as one passes over Mount Washburn.

Photo by Edmund Heller.

Fig. 93. Bighorn rams grazing on the dry hillsides in late autumn.

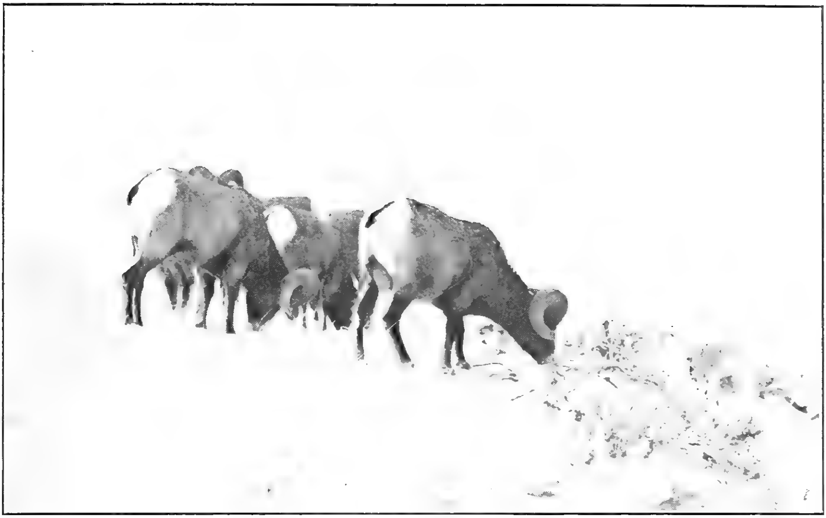

Photo by Edmund Heller.

Fig. 94. A group of old rams grazing through the snow on a sagebrush flat.

Photo by Edmund Heller.

Fig. 95. A band of old rams, closely bunched like domestic sheep, crossing a plateau.

Photo by Edmund Heller.

Fig. 96. Part of the so-called "tame herd" of Buffalo in the Lamar Valley in September, 1921. Secretary Fall's party observing the herd.

Photo by Edmund Heller.

Fig. 97. A closely packed herd, including all ages, at the buffalo ranch in the Lamar Valley. Specimen Ridge in the background.

ebb.* Unfortunately, deer cannot be held and grazed within the Park through the winter as can the antelope, as they will go higher on the hills and around or over the fence built across the valley flats to restrain the latter.

MOUNTAIN SHEEP OR BIGHORN

Ovis canadensis Shaw

The bighorns or mountain sheep are a source of much anxiety and concern to the Yellowstone Park staff. Their numbers have decreased rapidly since former times, but whether they are still declining is not known. My attempts to find them in summer and fall were not very successful, and I feel that they are, next to the white-tailed deer, the rarest hoofed game in the Park. In 1907 they were estimated by the rangers at 200, in 1910 at 150, and in 1916 at about 110. What their numbers are at the present time we can only guess. I saw in three months' search some 28 individuals, 12 of which were ewes and young lambs, and 16 were adult rams. The ewes had a fair proportion of lambs with them and seemed to be increasing normally. The rams were seen in late November after several heavy snowstorms. I should say that 100 bighorn sheep would be a very liberal estimate for Yellowstone Park, an area that should harbor at least 1000, after forty years of protection.* *

It is somewhat difficult to sift evidence concerning the decrease in the number of sheep. It is doubtful if many wander out of the Park as they are usually local in habitat and are not affected in the least by the severity of the winter weather. These animals are not nervous, and inhabit regions where they are not subject to molestation. They eat hay which is placed near Gardiner Canyon road in winter, but they do this merely as a change in diet and not because they are in want of food. There may be some killing of these native sheep by poachers in the eastern portion of the Park, but not to an extent that would account for their diminished numbers.

The reason that seems most plausible is that the bighorns were infected by "scab," contracted from tame sheep that were driven through the Park. Scab is caused by a mite, and in domestic sheep is not a fatal disease. To the bighorn it seems to be deadly. The ears are attacked first, and become closed, rendering the animal deaf. Tales came to us of sheep country in the Hoodoo Mountains in the

* The last of the white-tailed deer seem to have disappeared from the Yellowstone Park in 1923.

* In 1923 the bighorns were definitely seen to be increasing, over fifty being reported in one band on Specimen Ridge in August.

eastern portion of the Park, where many mountain sheep skeletons lie bleaching, supposedly those of victims of the scab epidemic. This epidemic was apparently at its height in 1916. We heard also that some of the animals were captured and transported in wagons to a dipping vat, and dipped. Most of the sheep dipped were said to have died, whether from scab or fright seemed to be a question. The animals that came under my observation in 1921 were in excellent pelage, and, so far as I could see, were free from disease. I regret that I had no opportunity to make a careful study of the problem of the disappearance of the sheep, or to check the authenticity of the rumors mentioned above. I believe that a careful investigation of the matter by a naturalist of experience would give us material by which to plan means to help them regain their normal numbers. I understand that domestic sheep may no longer be driven through the Park on account of the danger of transmitting their diseases to their wild relatives. But the native species will always be exposed to infection because of the fact that lone bighorn rams occasionally join flocks of domestic sheep for a few weeks at a time. Nevertheless, exposure to such infection should be cut down to a minimum.

Bighorn sheep are a source of much interest to tourists who motor or tramp over Mount Washburn, where a small band or two are occasionally seen from the roadside. One of their favorite ranges, except in midsummer when they usually seek the high and inaccessible peaks, is along the rim of the Grand Canyon near Tower Fall (fig. 91). It was at this point that President Roosevelt and John Burroughs camped in April, 1903, and watched the mountain sheep descend the canyon precipices to the river 600 feet below. John Burroughs has related their experiences most interestingly in his book entitled *Camping and Tramping with Roosevelt.*

The bighorns of the Yellowstone make excellent subjects for the skillful camera hunter (fig. 92),* for they are equally picturesque in the storms of winter or amid the mountain crags of their summer home.

The old rams which I encountered in the snow late in November were exceedingly fearless and unconcerned, more trustful even than horses and cattle (figs. 94, 95). These old fellows have an air of great solemnity and dignity, and their massive horns and heavy bodies give them an appearance of great strength and determination, the reputation for the latter quality, however, seldom being deserved.

* This photograph was awarded third prize in the exhibition of mammal pictures held at the American Museum in New York City, May, 1922.

Photo by Edmund Heller.

Fig. 98. Part of the buffalo herd crossing the Lamar River in September, the huge old bulls leading the way.

Photo by Edmund Heller.

Fig. 99. Old bison bulls held temporarily in the big corral at Mammoth in midsummer. These bulls approximate a ton in weight and are swift and dangerous antagonists.

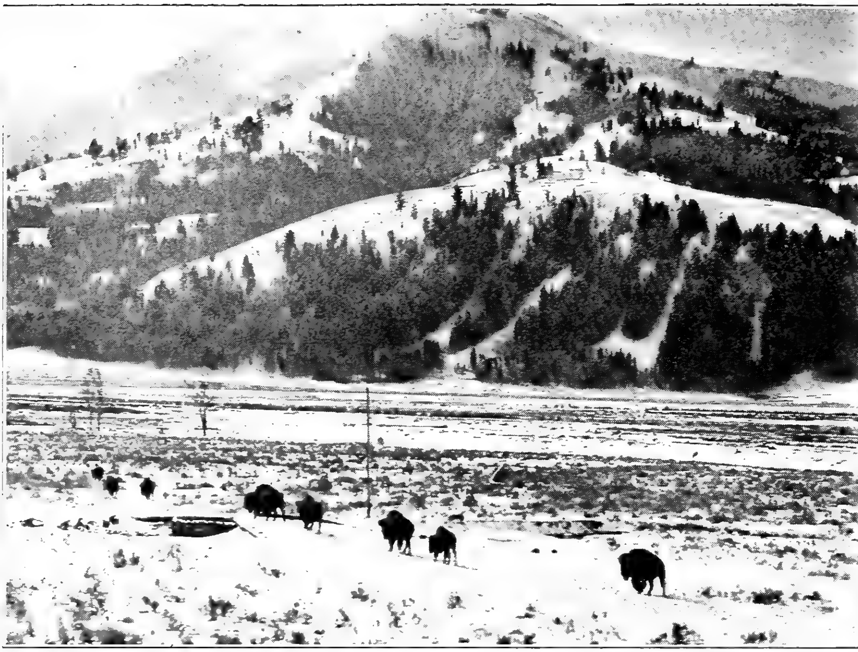

Photo by Edmund Heller.

Fig. 100. A rear guard of the buffalo herd crossing the Lamar Valley in winter. The storm-swept heights of Specimen Ridge and the Fossil Forest beyond.

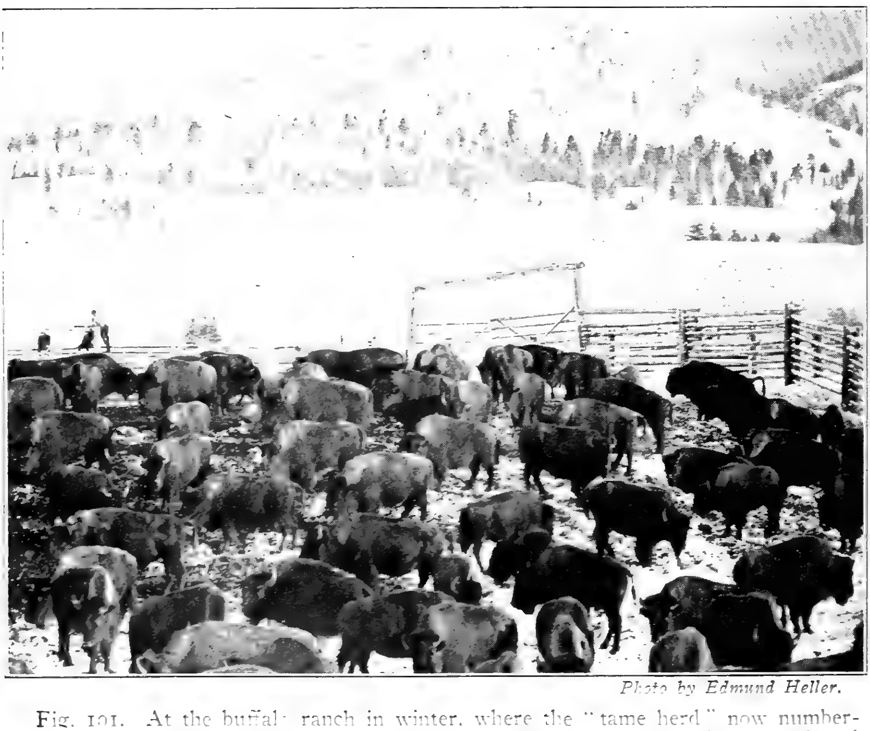

Photo by Edmund Heller.

Fig. 101. At the buffalo ranch in winter, where the "tame herd" now numbering about 600 is fed in immense corrals. In spring the herd is released and disperses to its natural grazing range on the mountain slopes.

BISON OR BUFFALO

Bison bison (Linnæus)

The safety point in the campaign to save the buffalo from extermination has long since been passed, and today these animals are almost as easily reared and managed as domestic cattle (fig. 101). The so-called tame herd of the Yellowstone, now numbering over 600 head, is increasing rapidly. There appears to be practically no disease among these bison at present, although several years ago an epidemic broke out which killed a number of the animals. This was diagnosed as hemorrhagic septicemia, a recurrent malady sometimes mistaken for "blackleg," and the calves are now vaccinated annually against the disease. Bison are apparently immune to the "blackleg" of cattle.

The buffaloes are very hardy and endure the severe winters of Yellowstone Park without loss from exposure and freezing. Nearly all of the cows breed annually and the death rate among the calves is low. Therefore, it may eventually become a problem as to what to do with the increase of the "tame herd," although the other National Parks and National Forests within the natural range of the species should harbor a considerable number to advantage. Many state game preserves and parks also will no doubt afford suitable range for bands of buffalo. Such areas should take care of the surplus breeding stock for many years. Zoological parks, on the other hand, are well stocked and require very few additional bison. The maintaining of private herds by wealthy stockmen has received a setback recently, owing to the considerable expense involved. If the ranger force were allowed to use the surplus male buffaloes in the form of beef it might be good economy; but this would be attended by grave risks, and would set a dangerous precedent. Under the present regulations of the Park none of its animals can be killed for food. The castration of excess bulls has been resorted to, but this of course does not reduce the number of calves born. It has proved very unsatisfactory, moreover, because the altered animals are inclined to fight the cows and otherwise act abnormally toward their fellows. They are merely disturbers and the herd would be better off without them. Considering the small number of bison now existing in the country, it would seem a safer procedure to disperse any surplus from the Yellowstone herd to other localities in their natural range, rather than destroy them. The sudden outbreak of disease in the winter of 1918, destroying thirty-six animals in a single epidemic before it could be controlled, and a similar sudden outbreak in March, 1922, when fifty-two buffalo died and the entire herd was threatened, indicates the still uncertain situation with respect to the safety of the species.

The tame herd, although it is of pure bison stock, was originally recruited from several sources. The Goodnight herd in the Panhandle of Texas furnished three bulls. Another band of eighteen bison came from the Flathead region of Montana. There is some Colorado bison blood in this tame herd, as well as a little from the Yellowstone Park wild herd; and a single bull of the woodland bison, racially distinct from the others, is said to have been introduced. A similar mixture occurs in the wild bands of buffalo now ranging the Kaibab Forest. These are the remnant of a herd gathered from several localities and introduced there by "Buffalo" Jones for the purpose of experimental breeding some years ago. The plan proved impracticable, and all the animals were removed except about twenty which were too wild to be rounded up. This remnant has recently been relocated; and one of the band is said to be conspicuous because of its *white* face.

The above cases represent an undesirable condition. The cattle breeder's practice of mixing strains should not be followed when dealing with wild animals for wilderness parks and preserves, as the strains from different localities may represent various races and subspecies. A mongrel stock is of little scientific and educational interest. On the other hand, there need be no fear of deleterious effects from inbreeding the buffalo. Such inbreeding is constantly occuring in nature. The mixing of wild stock is wholly at variance with the ideals of our National Parks,—wilderness areas set aside for their features of supreme national interest to be maintained in their wild and original state. This preservation of original natural conditions must apply to the large mammals and other wild life, no less than to the forests and mountain scenery.

The wild herd is the real bison prize in the Park, and every effort should be made to preserve it in a wild state and *without admixture from the other stock*. This large band is derived from the original remnant of our great western herd and owes its preservation to the fact that it was composed of individuals which voluntarily or under pressure from the hunters on the plains chose to winter in the Yellowstone Park region and did not join the great herds on their annual migration south in autumn. The descendants of these non-migratory bison today constitute *the only original wild herd* in the United States. Owing to their hardy nature they are able to winter success-

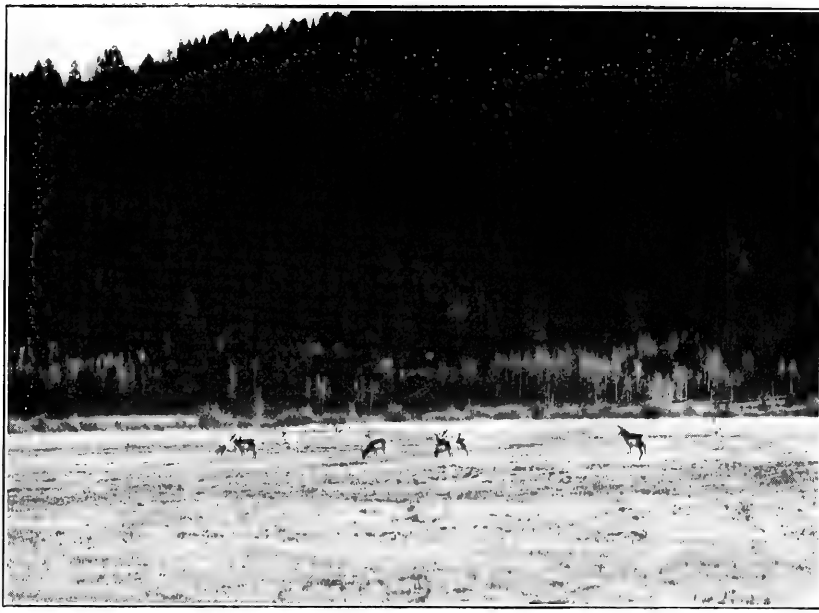

Photo by Edmund Heller.

Fig. 102. An antelope buck guarding his harem in September on the summer range in the Lamar Valley. The antelope usually keep to the open range, unlike the deer in summer.

Photo by Edmund Heller.

Fig. 103. The antelope on their winter range along the Gardiner River flats, November 18, 1921, just after the first snows in the valley.

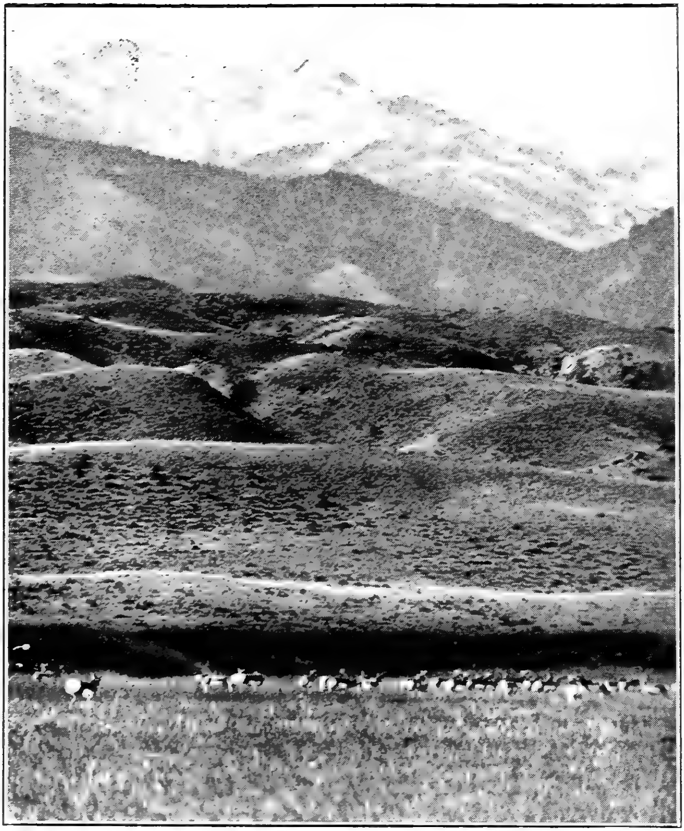

Photo by Edmund Heller.

Fig. 104. Part of the antelope herd in their present winter home, along the Gardiner River flats, at 5,400 feet, the lowest elevation in Yellowstone Park. Electric Peak, the highest point in the Park, towers nearly 6,000 feet above.

Photo by Edmund Heller.

Fig. 105. The entire antelope herd in the Gardiner Valley near the Park boundary, November 15, 1921.

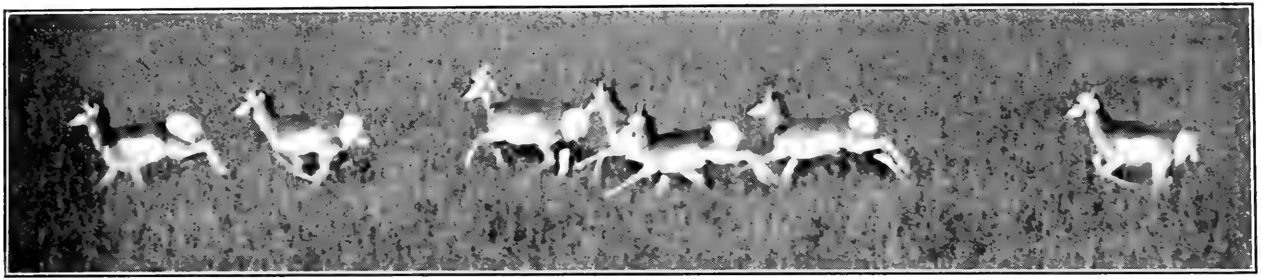

Photo by Edmund Heller.

Fig. 106. A band of prong-horned antelope, showing their characteristic bounding gait and flaring rump patches.

Photo by Edmund Heller.

Fig. 107. Frightened antelope, showing the appearance of the long, white hair of the rump when erected. This "flaring" is an alarm signal to other antelope.

Photo by Edmund Heller.

Fig. 108. An antelope with fully developed horns in October, a month before the horns are shed. Note the smooth white rump patch, indicating that the animal is not disturbed.

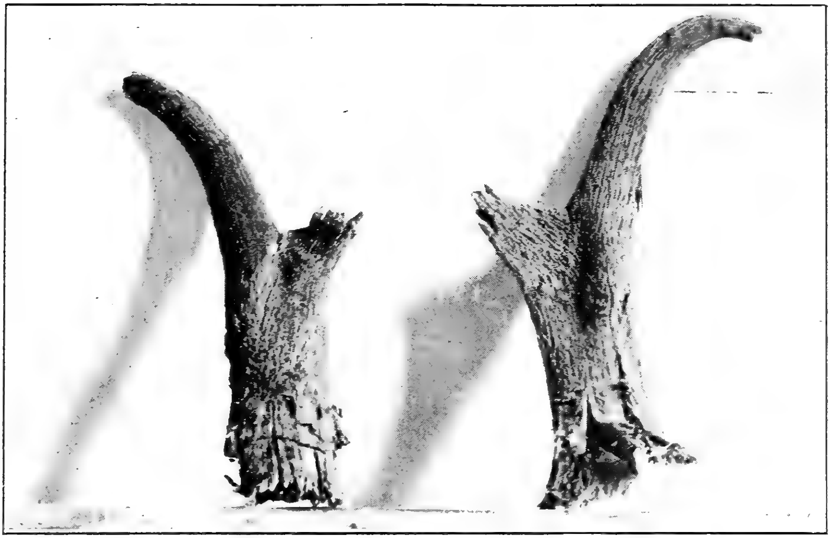

Photo by Edmund Heller.

Fig. 109. Weathered shells of antelope horns, the tips of which have been gnawed by rodents. These are cast in late autumn.

Photo by Edmund Heller.

Fig. 110. An antelope that has recently shed his horns. The horn cores and new sheaths, their basal half covered with fine hair, as they appear in November.

fully in their restricted range near the hot springs in the valley of Pelican Creek, at an elevation of 8000 feet. Mr. M. P. Skinner states that " here they manage to gain a scanty living from the grass freed from snow by the interior heat. Aside from deep snow this valley is a good place for them, affording as it does good protection from the bleak, wintry winds that sweep across the Park plateau. In summer they have ample grazing in secluded nooks." (See *The Hoofed Animals of the Yellowstone;* in *Amer. Museum Journal,* Vol. 16, 1916, pp. 86–95.) These bison are a pure indigenous stock living aloof in the wildest areas of the Park, entirely self-supporting, and still free from the epidemics that constantly threaten the imported mixed herd. They now (1922) number about 100 and are evidently doing well, having increased about forty per cent since 1917, when they are said to have numbered 67 animals.

As the buffalo range in scattered bands on the high mountain slopes in summer, very few Park visitors see the main herd. But a " show herd " of about twenty splendid animals is kept at Mammoth in an extensive pasture during the tourist season (fig. 99), and thousands of people have full opportunity to observe and photograph them to best advantage. These bison are returned in the fall to the Lamar Valley, where the entire tame herd is rounded up in the vicinity of the "buffalo ranch " for the winter (figs. 96–98). Here the calves are vaccinated against disease, and all are fed during severe weather on hay cut and stacked at the ranch.

PRONG-HORNED ANTELOPE

Antilocapra americana (Ord)

In the natural range of our antelope northern Yellowstone Park represents the extreme upper limit of summer distribution. It was never intended by nature as a year-round home for these animals. No prong-horns wintered in the Yellowstone in the old days when they could exercise their migratory instincts and travel down from the foothills each autumn to snowless plains for their winter residence. Holding the antelope in the Park in winter seems a rather cruel procedure, but heretofore it has appeared to be the only means of saving them. If it were possible to herd them like cattle, or allow them to drift lower down to some favorable warm valley for the inclement season, they could lead a far happier life and their increase might be assured. This experiment of letting them down to a ranch below the Park was tried in the winter of 1922–1923, with apparent success. But on the other hand the prong-horn is too nervous an animal for such treatment, and there is the added danger of the whole herd becoming suddenly scattered and lost forever. If the Park boundary could be extended even a few miles north along the Yellowstone Valley, this would probably save the antelope. It would also assist in the protection of the deer and the precious herds of elk, now in a precarious situation.

It appears to be principally because of the severity of the winters that the Yellowstone antelope are gradually diminishing in number. In 1912, it was estimated that there were about 300 in the Park, and today there are less than 200 all told. How long will they last in case their Park range is not extended down the Valley? None of the other remaining bands in the United States has such severe climatic conditions to meet as those wintering below Mammoth Hot Springs, but for one cause or another they are all apparently tending rapidly toward extermination. On the other hand, the Yellowstone herd receives better protection from poaching than those outside the National Parks. The American antelope is very sensitive and nervous in disposition and fails to breed regularly when reduced in numbers or disturbed. If placed in confinement, as in a zoological garden, it soon dies. In order to preserve our antelope they must be kept in large herds and carefully guarded from all disturbing influences. They are easily driven from their range, the approach of a single person or unusual object being sufficient to stampede and scatter them over a wide area. On various occasions portions of the Park herd have broken away over the northern boundary and been destroyed. Such losses account in part for the diminished numbers of the present herd. No person or institution should now be permitted to shoot or take antelope anywhere *for any purpose whatsoever.* Every animal in the few existing bands is needed to help build up the race to a point where it will breed normally and re-establish its former numbers. A safe margin should always be maintained to allow for possible accidents to so sensitive a species.

No game animals in America are worthier of preservation than the antelope. Their home is the open plains, where they would be visible to everybody traversing their habitat. No more lovely sight ever gladdened the eye of a traveler than that of a band of these spritely pink and white creatures. Their eyes are unusually large for the size of the animal, and their color pattern is strange and very beautiful (figs. 108, 110). Prong-horns have a peculiar bounding gait (fig. 106) and are capable of tremendous speed. When frightened they "heliograph" their alarm to their companions by reversing the white hair of the rump, which reflects the sunlight in mirror-

Photo by Edmund Heller.

Fig. 111. A buck antelope which has shed it horns, showing the cores over which the new pronged sheath develops. Beyond him stands a doe with characteristic tiny horns.

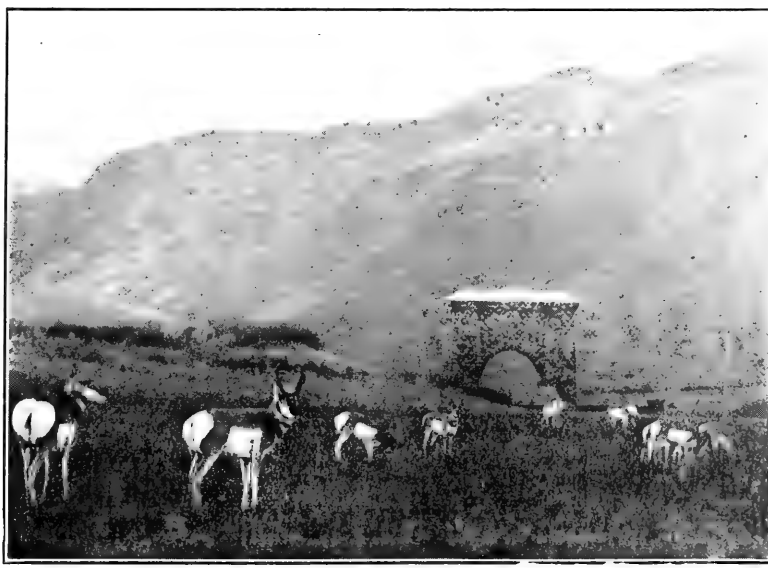

Photo by Edmund Heller.

Fig. 112. The archway at the northern entrance to Yellowstone Park, dedicated by President Roosevelt in 1903. The boundary fence across the Gardiner River flats at this point helps to hold the antelope (but not the elk and deer) from migrating down the valley to their natural winter range, where they would be slaughtered by Montana hunters.

like fashion and is visible for a long distance (fig. 107). In habits they are polygamous, one buck usually being in possession of five to twelve females which he drives before him. The excess of bucks is usually noticeable close by, associated as they are in bachelor parties waiting for a chance to break into society and displace any patriarch whose fighting ability is declining.

The American prong-horned antelope shed their horns, which are hollow like those of true antelope. But these animals alone among hollow-horned ruminants exhibit this characteristic of shedding. A new horn has already begun to form under the old shell so that the animals are never really without horns (figs. 110, 111). It was my good fortune to be with the Yellowstone herd daily during this period when the horns were lost, and photographs were taken on consecutive days to verify the field observations. The shedding process started in the first week of November and within a fortnight all the bucks had dropped their old horns. Several pairs of shed horns were found on the range at this time.

I first observed the Yellowstone antelope on their summer range in the Lamar valley in mid-September. The young are born in June; and those which I saw in September were half the weight of the parents, nearly as tall, and much more alert and fleet of foot. At that date the animals appeared to be in harems and this condition was maintained until October 10, when they gathered in larger bunches and migrated down the valley close to the town of Gardiner, where they formed a large herd within the four-mile fence extending across the Gardiner valley at the Park boundary. Here, on a range but a few hundred acres in extent, most of them spend the winter (figs. 104, 105). The winter of 1921–1922 was severe and about 125 of the animals died of exposure or were killed by beasts of prey which trapped them in the crusted snow along the boundary fence.

For a more detailed account of this remarkable species, based on this study in the Park in 1921, the reader is referred to *The Vanishing Race of Pronghorns*, by Edmund and Hilda Hempl Heller (*Travel*, Vol. 41, No. 2, June, 1923, pp. 5–10). For the most complete account of the Yellowstone antelope, see *The Prong-horn*, by M. P. Skinner (*Journal of Mammalogy*, Vol. 3, No. 2, May, 1922, pp. 82–105), and a revised reprint of this, 1924.

As the Yellowstone region comprises our last great wild life refuge, outside of Alaska, the loss of such vanishing species as the antelope and grizzly bear, or the last small herd of truly wild buffalo, would be a calamity; for nothing holds the popular interest in this great Park more than its wonderful display of animal life. The bordering states of Montana, Wyoming and Idaho should therefore cease their indefensible practice of maintaining open shooting seasons near the Yellowstone Park borders. This practice is equivalent to poaching on the Park preserve, for the large mammals are influenced in their movements not by the purely artificial boundaries of this area, but by the natural topography of the country. The citizens of the surrounding states derive a large and rapidly increasing annual revenue from the Park tourists, and they should be foremost in giving protection to the game which wanders into their territory. If they are actuated by no higher motive, at least it would be good business for them to protect "the goose that lays the golden egg."

If adequate measures are taken to study and save the large mammals at the present critical stage, it will mark the beginning of constructive management of a wild life resource invaluable alike to science and to educational recreation in our parks. But the danger of complete loss and the extreme difficulty of restoration of the diminishing herds is realized by few people. Every visitor to the Yellowstone should feel a personal responsibility and solicitude for its wild animals, as for its other priceless treasures, and should take a keen interest in the problems of their true appreciation and their preservation for all time.

WILD LIFE AND DEMOCRACY

"Above all, the people, as a whole, should keep steadily in mind the fact that the preservation of both game and lesser wild life — by wise general laws, by the prohibition of the commercialism which destroys whole species for the profit of a few individuals, and by the creation of national reserves for wild life — is essentially a democratic movement. It is a movement in the interest of the average citizen, and especially in the interest of the man of small means. Wealthy men can keep private game preserves and private parks in which they can see all kinds of strange and beautiful creatures; but the ordinary men and women, and especially those of small means, can enjoy the loveliness and the wonder of nature, and can revel in the sight of beautiful birds, only on terms that will permit their fellow-citizens the like enjoyment. In other words, the people as a whole through the government, must protect wild life, if the people as a whole are to enjoy it. This applies to game also."

THEODORE ROOSEVELT and EDMUND HELLER.
Life Histories of African Game Animals,
Vol. 1, pp. 155–156, 1914.

WILD LIFE RESEARCH IN THE YELLOWSTONE

"This whole episode of bear life in the Yellowstone is so extraordinary that it will be well worth while for any man who has the right powers and enough time, to make a complete study of the life and history of the Yellowstone bears. Indeed, nothing better could be done by some of our outdoor faunal naturalists than to spend at least a year in the Yellowstone, and to study the life habits of all the wild creatures therein. A man able to do this, and to write down accurately and interestingly what he had seen, would make a contribution of permanent value to our nature literature."

THEODORE ROOSEVELT,
Outdoor Pastimes of an American Hunter, p. 315, 1908.

Photo by E. R. Warren.

Fig. 113. View down the rapids of the Yellowstone River at the entrance to the lower part of the Grand Canyon, below Tower Fall, showing the "palisades" and the rock columns known as "the needles."

THE FOOD OF TROUT IN YELLOWSTONE NATIONAL PARK*

By Dr. Richard A. Muttkowski

Collaborator, Roosevelt Field Naturalist, Roosevelt Wild Life Forest Experiment Station, Syracuse, New York

CONTENTS

INTRODUCTION

Through the courtesy and cooperation of the Park authorities, the Yellowstone Park Camps Company, and the Roosevelt Wild Life Station, the writer during the summer of 1921 was enabled to make certain studies of the trout streams of Yellowstone Park, particularly those of the northeastern section. The study extended through four months—from June 20 to September 10,—covering the critical period of the year, since the conditions during these months largely determine the propagation of trout and also of their natural food supply.

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* Contribution from the Roosevelt Wild Life Forest Experiment Station, and from the Zoological Laboratory, University of Idaho, Moscow, Idaho.

This is the third of a series of papers on the wild life of Yellowstone National Park which has been made possible by gifts to this Memorial Station from the joint friends of Theodore Roosevelt and of wild life conservation. The initial aid for this plan came from Mr. Howard H. Hays, President of the Yellowstone Park Camps Company. I gladly avail myself of this opportunity to thank Mr. Hays and Dr. Muttkowski on behalf of the Roosevelt Wild Life Station for their contribution and cooperation in this investigation. (Cf. also *Roosevelt Wild Life Bull.*, Vol. 1, No. 1, pp. 96–99.)—The Director.

While dealing specifically with the trout streams of Yellowstone Park, the facts here presented have a much wider application. It is an axiom that like causes beget like results. In a broad sense the mountain trout streams of the Park and their fish are typical of the trout streams throughout the Rockies. The writer has had the opportunity to make comparisons of physical conditions, and to some extent of the biological conditions, in several of these states. In the region studied, the conditions affected but a single species of trout—the native redthroat, cutthroat, or blackspotted trout (*Salmo clarkii*)— the only one found in the northeastern part of the Park.

The present account is not in any sense complete, as it deals with only a few phases of the work, certain summaries presented in a form believed to be of most interest and value to the general reader. The technical, detailed report is to follow at a later date.

The illustrations accompanying this paper, with the exception of figure 113, are reproduced from photographs taken in 1921 by the author.

FISHES AND THEIR ENVIRONMENT

There are at least two points of view in dealing with fish,—that of the fish and that of the fisherman. A fish wants something to eat, and the fisherman, aside from a secondary " sporting " interest, wants to eat the fish. What the fisherman thinks we known pretty well. But no one has as yet succeeded in interviewing a fish directly to find out what he "thinks" about the matter. Indirectly, scientists have frequently forced fish to give us information by placing them under special, controlled conditions. This method is called experiment. To this is added observation. By combining the results gained by the two methods a good deal of information has been accumulated regarding a fish's habits, his likes and dislikes, and something of the world in terms of a fish's life.

Let us summarize briefly the conditions under which a fish lives. Water is supposedly transparent. But have you ever looked at the under side of the surface film of water in an aquarium? Seen from an acute angle, this surface film is not at all transparent, but acts as a mirror, reflecting the objects beneath. The more closely the angle of vision approximates a right angle the less the mirroring, and the greater the transparency. There is a further difference whether one gazes toward the sunny or shaded side of the water. A fish can see objects outside of the water, provided these are fairly above him, at an angle of view not exceeding 45 degrees, or within an arc of approximately 90 degrees. Beyond that point the surface film becomes a mirror to the fish. These points can be easily tested by any person with sufficient courage to keep his eyes open under water for a few seconds. There is a slight difference in a stream where the surface is mobile, as in rapids. Here the effect is primarily that of a " freak " mirror, constantly moving like a dish of agitated mercury or molten silver or lead, with bright streaks and dark bands, the bands being transparent places.

To the fish, then, the water surface is in good part a mirror, through which he cannot see; but he does see objects beneath him reflected plainly in the surface mirror — upside down, of course. This is an advantage, for it aids him to find the food in the water, to come upon his prey suddenly, unobserved, and from an unexpected angle. It is also to his disadvantage, for while it aids him in finding his prey, it exposes him to his enemies in the water, putting him in the position of prey. It places him at the further disadvantage of not being able to see external enemies, such as man, birds, and fishing mammals, except through the circumscribed area directly above him. And finally, the mirror tricks him into accepting bait that is poked through the surface mirror while preventing him from seeing the fisherman on the shore who is offering the bait.

Another point is that fish are more or less near-sighted and do not recognize objects unless they move. Further, a good deal of scientific evidence indicates that fish are color-blind, that they do not see colors as we do. To fish, all colors apparently must be more or less shades of gray, much as to a color-blind person. If this is true, in just what way are colored flies so useful when used as bait for fish, since fish are not supposed to recognize colors as we do? Again, since a fish generally strikes from below and sees the colors of bait *against light,* of what use are colors under such conditions? To test this, let the reader try to recognize colors of an opaque object held against light. Whether a fish recognizes colors as such, or merely as shades of gray, is as yet an unsettled question which offers splendid opportunity for experimental study.

For the observer who wishes further information on this interesting subject, the following references are suggested:

The Senses and Learning in Fishes, by Jacob Reighard. In *Transactions Amer. Fisheries Soc.,* Vol. 46, No. 3, 1917, pp. 133–170.

Marvels of Fish Life, as Revealed by the Camera, by Francis Ward. 2nd ed., pp. 1–196. London, 1912.

Animal Life Under Water, by Francis Ward. Pp. 1–178. New York, 1920.

THE FOOD OF THE NATIVE REDTHROAT TROUT

The habits of fishes are as varied as those of terrestrial animals. Fish are carnivores, first of all. But the different kinds of fish have their preferences in the way of food. A silver bass is primarily a surface feeder, that is, he prefers to pick his food from the water's surface or from plants near the surface. Both the large-mouthed and small-mouthed black bass are chiefly plant feeders, selecting their food from plants, while the crappie is more or less an indiscriminate feeder, although he really prefers the muddy bottoms. The trout, in general, are clean feeders; that is to say, they do not like to skim the bottoms, but prefer to catch their prey when the latter moves through the water.

In mountain trout streams the rapidity of the current limits the make-up of the fauna to such animals as are adapted to withstand strong currents. In rapids one finds no leeches, no worms (except flat-worms), no air-breathing insects, nor crustaceans (crayfish, water-fleas, etc.). This limitation means that the food supply is confined to such plants and animals as can withstand the strong current either by strong clinging or propelling devices. It also means that the fauna consists of relatively few species, which generally are present in enormous numbers. It means further that the diet of the fish inhabiting such streams is limited to these items primarily and that, humanly speaking, the diet must become monotonous.

The food of trout can be conveniently classed into two types: *water bait,* which is the normal supply found in the water, and *surface bait,* consisting of insects and other animals that have fallen into the water and become "water trapped." This latter condition applies when an insect's wings become water-logged or so adhere to the surface that the insect cannot rise from it. This surface bait may be of various types, such as ants, grasshoppers, beetles, moths, butterflies,— in fact, anything that a sudden gust of wind may carry onto the surface. It may even include frogs, mice, worms, and other stray land animals.

The Water Food.— The normal food of trout streams, comprising the water bait, is represented in the main by three groups. Named in the order of their importance, for trout streams only, these are the Perloidea or stone-flies, the Ephemerida or May-flies, and the Trichoptera or caddis-flies.

Stone-flies.— The Perloidea or stone-flies are the most conspicuous fish food item in the Yellowstone streams. In this respect, these

Fig. 114. Stone-fly nymphs from the Yellowstone River near Yellowstone River Bridge.

Fig. 115. A stone-fly nymph (*Pteronarcys californica*) which has just come out of the water and is crawling up a rock to a sheltered spot for transformation to the adult insect. Photo July 25.

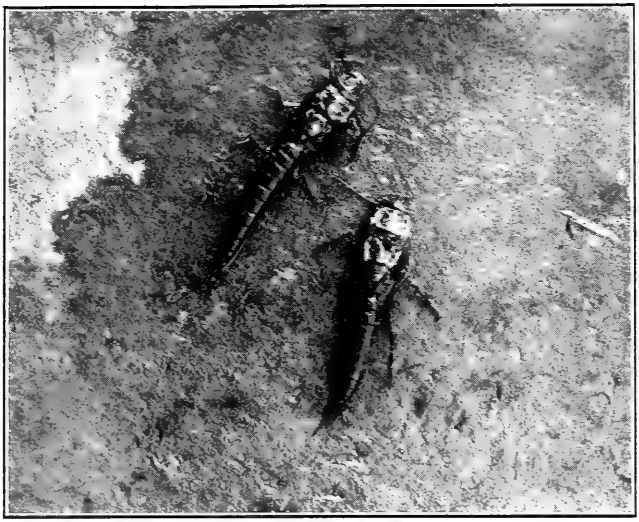

Fig. 116. Salmon colored stone-flies (*Pteronarcys californica*) "emerging" from the larval skins. In the upper specimen the larval skin has just split; in the lower one the head and legs are free. Photo July 25.

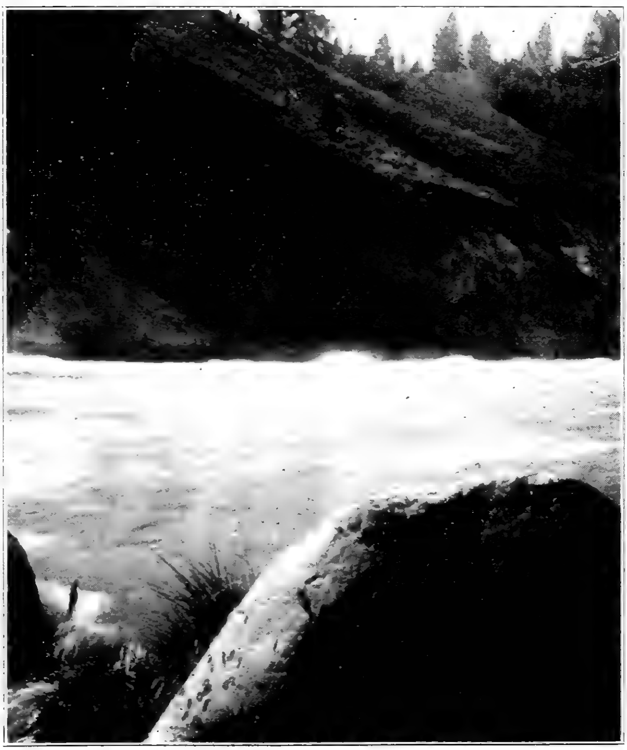

Fig. 117. Stone-flies "emerging" on a rock near Yellowstone River Bridge. Some of the dried cast larval skins are sticking to the rock. Photo July 6.

streams, especially where there are trout, are like other mountain streams. Indeed one may say that the life of trout streams as far as the fish are concerned is absolutely dependent on stone-flies. They are indispensible in the natural propagation of trout. While in the water, they are more or less flattened, six-legged creatures (fig. 114), varied in color and size, and generally may be found under stones or clinging to them, busily searching for food. Hence they are known to zoologists as "stone-flies." Most of them are carnivores in the aquatic stage; they eat other insects, flatworms and other aquatic animals, and even turn cannibal, eating their own kind or their young. Curious to say, the largest and most conspicuous species of the stone-flies (*Pteronarcys californica*) found in the rivers of Yellowstone Park is almost entirely herbivorous, eating the various algae and diatoms off the rocks, and also bits of wood and bark that come down the stream.

Beginning with July, the stone-flies "emerge," that is, they crawl out of the water onto the shore or on exposed rocks, split the larval skin, draw out the thorax, head, legs, and finally the abdomen, and expand their two pairs of wings (see figs. 115–116). They generally come out in enormous numbers from early morning till early afternoon. After the wings are dried, which takes from ten to fifteen minutes, they fly toward some upright object. Naturally, any person standing or moving along the stream will be taken for a convenient resting place by the stone-flies, much to the delight of the trout fishermen who encounter flights of these beautiful creatures.

According to local habit, these stone-flies are known by various names in different sections of the country. Thus, they are called willow flies, trout flies, mountain flies, salmon flies, yellow flies, river flies, red flies, black flies and so on, according to color, place of occurrence and the fish found in the particular neighborhood.

Stone-flies are almost wholly confined to rapid streams (figs. 117–119), as their distribution is controlled by the degree of aeration of the water. Since wave action along the shores of lakes provides fair aeration, stone-flies are found also along lake margins, although not in such profuse numbers as in the mountain streams. They are but seldom found in quiet streams or ponds and then only in relatively small numbers.

After becoming winged they generally spend the day in short flights and in copulation (figs. 120, 121). In the dusk of the evening they fly upstream for considerable distances and then oviposit. This is not a nuptial flight, for mating appears to precede the flight, but an instinct to go upstream for better distribution, which is more readily understood in view of the fact that the eggs are formed into a loose clump of 200 to 300 by the females and these clumps are washed off in the current to scatter as they may. The adults do not live more than three or four days. More, however, are eaten by the birds, both dusk-flying and day-flying species, than die naturally; and also by snakes, frogs, spiders, and even by ground squirrels. At the flight period one finds thousands of wings torn from the stone-flies and scattered along the shores of the streams,—evidence of destruction by their enemies. The hot sulphur springs along the Yellowstone River (see fig. 122) account for the death of other thousands. Whatever the attraction the springs exert upon the stone-flies,—whether heat, odor, or color,—this much is certain: hundreds of the insects fly to the springs and are literally boiled.

The transformation period lasts about ten days for a single species. After that, only isolated stragglers come from the water to transform into winged adults. However, as there are some eight to ten species of stone-flies in Yellowstone Park alone, and the total period of transformation covers some six weeks with slight overlapping, one may find stone-flies for a good part of the summer. Of these the large salmon-colored stone-fly (*Pteronarcys californica*), growing to a length of two and one-half to three inches, with a wing expanse of four inches, is the most numerous and conspicuous. After that, the sizes dwindle down through the black stone-fly (*Acroneuria theodora*, two by three inches, the yellow stone-fly (*Acroneuria pacifica*), one and one-half by three and one-half inches, the dusky stone-fly (*Perla verticalis*), one by two inches, to the green stone-fly (*Alloperla lineosa*), which is barely half an inch long and has a wing expanse slightly exceeding an inch. Only the first three can be called abundant. The transformation periods of the salmon-colored and yellow stone-flies coincide, and occur early in July, that of the black stone-fly not till early August. As regards these dates, one important fact should be noted; namely, transformation appears to be largely dependent on the temperature of the water. Where a stream is open the water will heat more rapidly from the sun than where a stream flows through steep-walled canyons. Thus, in the Yellowstone and Lamar rivers the stone-flies in 1921 transformed much earlier in sunlit open places than in the canyons. In the open stretches of the Yellowstone River between the Grand Canyon and the Lower Canyon (the "Needles,"—see fig. 113), transformation occurred nearly a week earlier than in the canyons proper. This was true also for the black stone-fly. This species transformed a week earlier in the

Fig. 118. Tower Creek, looking down the gorge; from junction of Carnelian Creek (right) and Tower Creek (left). Photo Sept. 6.

Fig. 119. Rapids just above Yellowstone River Bridge, on Cooke City road. Detail of foreground shows lesser rapids and pockets which form the feeding grounds of young fish. Photo Aug. 15.

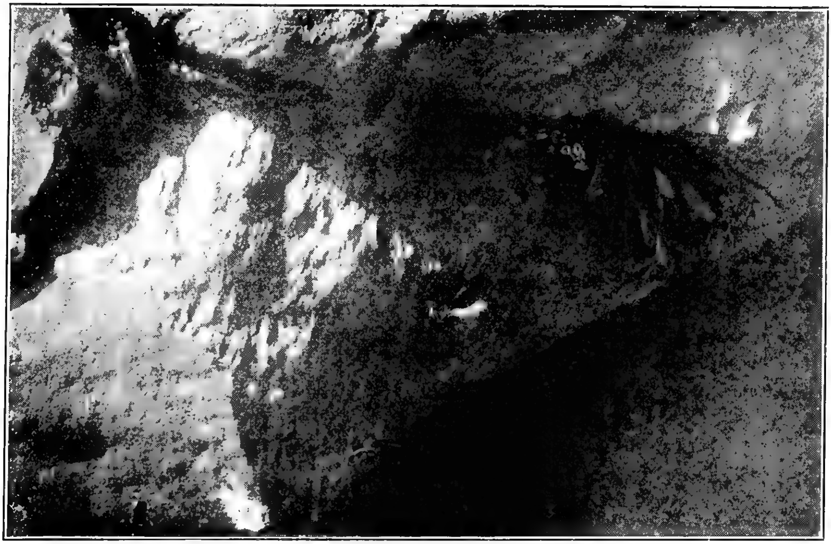

Fig. 120. Stone-flies in characteristic clusters, often as many as twenty individuals, in crevices of rocks along the lower Lamar River. (See also figure 131 for general habitat.) Photo July 6.

Fig. 121. Stone-flies mating on shore grass along the Yellowstone River. Photo July 6.

open Lamar River, Gardiner River, and the meadows of Slough Creek, than in the gorges of the Lamar, Slough Creek, and the much-shaded Lava Creek.

Another factor possibly is the light which may stimulate the species to transform in early July. By this is meant both the light of the shores and the light that penetrates the water. It has been noted that in open, sunlit places transformation occurs earlier than in the gloomy canyons. The amount of light to penetrate the water is variable. The spring floods carry great quantities of sediment which hinders the penetration of light. This makes the situation equally difficult for fish and for the fisherman. For where the one cannot see much in the line of prey in the water, the other cannot see the fish, nor pick the likely places to cast. Perhaps this turbidity accounts for the fact that when the floods recede and the water grows clearer the trout are hungry and "rise" more readily to bait; for it is obvious that the gloom resulting from the turbidity makes hunting difficult for the fish, and at a time when he needs an excess of food for the propagation of his kind.

On the other hand, it has already been remarked that certain species of stone-flies, such as the black and green stone-flies, do not emerge until August, hence long after the floods have receded and the water has clarified. Whichever the factor may be that chiefly stimulates transformation, whether light or temperature, prolonged study and experimentation are needed for its definite determination.

From the examination of hundreds of stomachs of trout, especially the cutthroat trout (*Salmo clarkii*), it is evident that stone-flies, both in their larval stage in the water and after transformation, form about 90 per cent of the food of the trout. The foregoing merely confirms what others have found as regards the dependence of fish life in rapid streams on stone-flies for food. It is a curious fact that some of the mountain streams which have a very low representation of stone-flies will not support fish life, or at least trout life.

May-flies.—The second and third groups, namely the may-flies and the caddis-flies, are variable in their representation and appear to change their position of importance according to the stream. In the Lamar River, for instance, the caddis-flies outnumber by far the may-flies, while in the Yellowstone River, Lava Creek, and other streams the may-flies are more conspicuous numerically. Whatever the cause of this variability, they appear to be equally abundant in the fish stomachs.

May-flies are otherwise known as day-flies or shad-flies. They have their names from the fact that they live but one day in the adult or winged stage, live only to reproduce and die, or to fall a prey to birds, mice and other animals. In the streams of the Middle West they are important as scavengers. They generally emerge in enormous numbers, but for one day only, and then they are gone. In some streams in Europe it has been noted that certain species emerge on definite dates; in fact, within stated hours on a given day, year after year. Much speculation, but little evidence, exists as to the factors which control this remarkable synchronism.

In their aquatic stage the may-flies are of varied form, some of them very flat and found under rocks (fig. 123), some swimming about with quick, minnow-like darts, and some with elaborate gills by means of which they propel themselves. All have gills for breathing air from the water, some of the gills being thread-like, others flat, and still others attached to slender stalks like leaves to a branch. Some have elaborate processes on their heads for burrowing. These, however, are found primarily in muddy streams, and in lakes and ponds. In the mountain streams none of the burrowers occur.

After transformation, the adults have two pairs of wings, the fore wings large and triangular, the hind wings very small and inconspicuous, indeed, sometimes entirely absent. Also, they generally have from two to three fine tail filaments.

In the mountain streams, their transformation is spread over a considerable period, so that they are but little noticed. In the more temperate and quiet streams they transform in one mass and fill the air for a brief period for one or two days, and then disappear.

Caddis-flies.—The third group, the caddis-flies, derive their name from the fact that nearly all of them, in their aquatic stage, build cases from bits of stone, wood, or fibres, or weave a net which they attach to stones. These cases are infinitely varied in form, and from the standpoint of craftsmanship are intensely interesting. In the mountains one finds three types especially abundant. The first is that of the "barnacle" caddis-worms (*Rhyacophila* sp.), which build their cases in large clusters from tiny stones (see fig. 127). The second is that of the "picket" caddis-worms (*Limnephilus* sp.), which build square cases of neatly paralleled series of plant fibers. Since the cases are fastened to the support by their bases and stand out at right angles, the name "picket" is quite appropriate (figs. 126, 127). The third type is made up of extremely minute particles of sand and secretion gummed together to form a conical, gently-curved cornucopia about half an inch in length. Just before transformation, caddis-flies, like moths and butterflies, go through a resting period, called the "pupal" period, in which the change from grub to winged

Fig. 122. One of the hot sulphur springs along the Yellowstone River. This particular spring lies at the base of a hollowed rock shown in upper middle of figure 119.

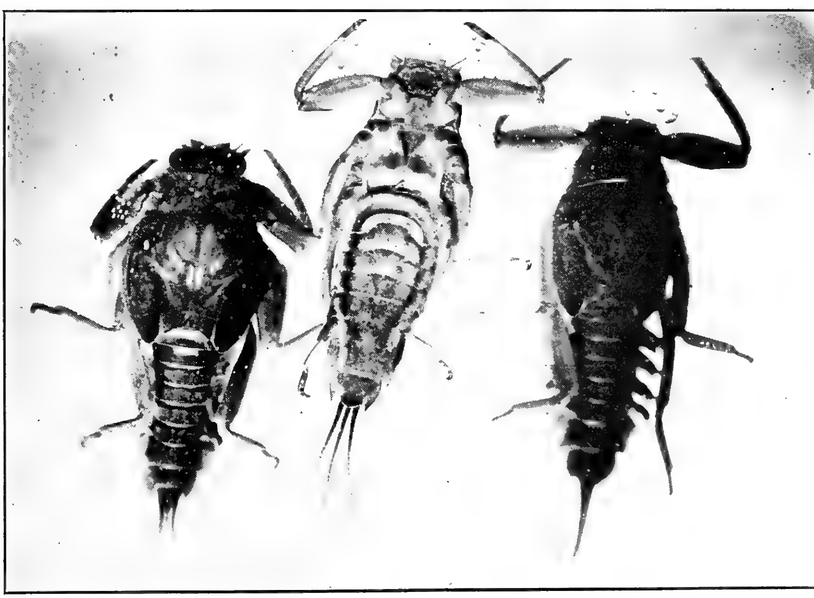

Fig. 123. May-fly nymphs from the Lamar River; four times actual size. Middle specimen turned over to show the "sucker" on under side, by means of which this particular species clings to rocks.

Fig. 124. An adult may-fly with a parasitic worm emerging from the caudal end. Enlarged eight times. Note the loop formed by the parasite within the abdomen of the host.

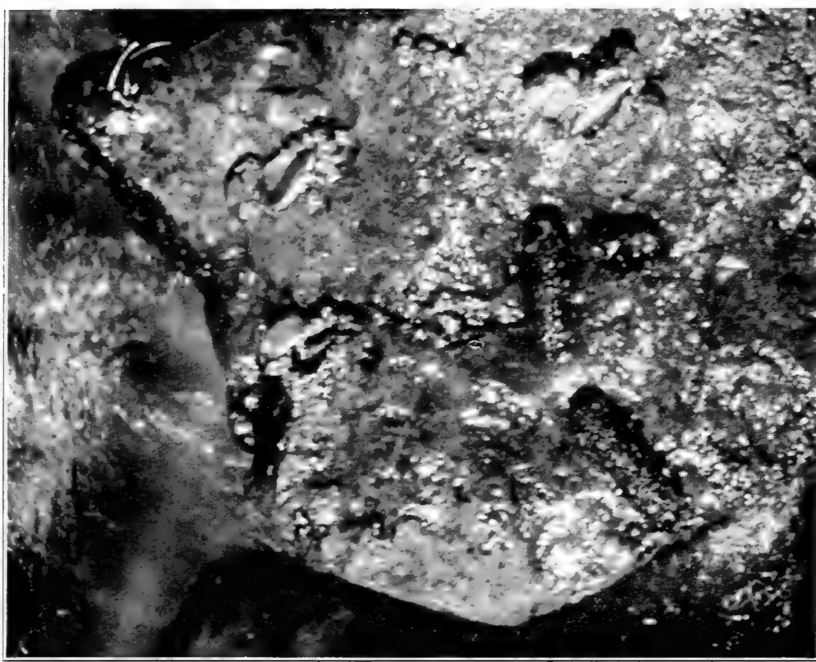

Fig. 125. An association of caddis-worms in their cases, attached to a wet rock. Four types of cases are shown on this overturned rock on the margin of Lost Creek. Photo July 27.

adult takes place. During this pupal period the "cornucopia" caddis-worm (*Leptocerus* sp.) seeks the under side of rocks; there the individuals cluster together, forming prickly patches which resemble a cluster of dead spruce needles or the spines of a porcupine (figs. 128, 129).

Still another species of the mountain waters builds itself a network which it anchors with stones (*Hydropsyche* sp.). The net is in the shape of a funnel, with a sieve across the wide end, and the smaller end directed downstream.

In the grub or larval stage the caddis-flies are particularly interesting because of their manifold structures. They resemble caterpillars; in fact, they are the nearest relatives of the moths and butterflies. They have tufts of filaments on their bodies, a head and six legs resembling those of caterpillars, and two posterior legs provided with hooklets which serve as grapples or claws to anchor the worms in their cases.

In the mountain streams none of the caddis-fly species are free swimmers; that is, their cases are all fixed. What migrating they do, is done slowly and laboriously. In the lakes, ponds and quiet streams one may find species with square or spiral cases swimming about freely.

After transformation the adult caddis-flies resemble tiny moths. Indeed, they are often mistaken for moths, even by scientists, and have been thus described. They like to gather on the rocks along the shores of streams, where they run back and forth briskly, or fly about the rapids, alighting on the water's surface and flying up into the spray. They may even dive into the water, for the water does not wet their wings and body. Only prolonged submergence will water-log them.

The Surface Food.—Besides these main items of the normal trout diet in the mountain streams, the so-called "water bait," there is the surface drift or surface bait of water-trapped animals, chiefly insects. This comprises especially the weak fliers such as moths, ants and grasshoppers, while spiders, centipeds, mice, and other animals may occur. But the life of a trout stream is dependent on its normal inhabitants, not on the odds and ends which a kind wind or accident may provide. It is only during the brief summer period that surface bait becomes important; and for a period of four to six weeks the fish are largely dependent on this type of food for their existence. That the emergence of their natural water bait, with the resulting depletion of this primary food supply, should be synchronous with the summer flights of ants, moths, grasshoppers and other poor fliers that are easily water-trapped, is one of many instances of the admirable provisions of nature.

Indeed, this is carried still further at this period. At this time the minute life of the shore waters, especially the shore diatoms, flat-worms, chironomids, and the young stages of may-flies, stone-flies and caddis-flies, receives a tremendous impulse and becomes quite prominent. At this period also the young of trout, suckers and other fish in the mountain streams can be found in the shore pools and shallow rapids feeding on the minute organisms in these places. Here lies the remarkable coincidence: the simultaneous appearance and growth of fish fry and of a protected food supply for its use. For the older trout are unable to get into these shallows, which therefore offer both protection and food to the young fish (figs. 119, 130).

From the foregoing it is evident that there exist only two well-marked periods in the annual cycle of mountain trout streams, namely, a "water food" period covering nearly eleven months of the year, and a "surface food" period, occurring during the summer, and lasting from four to six weeks. This is the period when trout, as anglers put it, "rise to bait." These same periods might also be called flood and ebb periods, or flood and drought periods, from the fact that high water lasts from October to July, while the ebb or low water stage of the summer is really very brief.

With the fall rains the brief low water stage ceases and the conditions revert to those existing during winter and spring, and continue to the time of emergence described, that is, about the first week of July.

FEEDING HABITS OF THE TROUT

From the examination of fish stomachs it is possible to deduce much about the food habits of fish. First, fish will take food that is easily captured; secondly, that which is accessible with difficulty; and lastly, strange and unusual food. Of the food available in mountain streams, stone-flies and may-flies are most easily obtained and constitute the major portion of the food eaten. Here, too, the eggs, fry and fingerlings should be listed, as fish are cannibals when opportunity offers; and trout are no exception, but will eat other fish just as greedily as will bass. Caddis-flies, well protected by virtue of their tough attached cases, and moreover, even more inaccessible on account of the appressed structure of many cases, rank in the second category, and for that reason constitute a much smaller item of fish food than the other two groups of insects. However, they

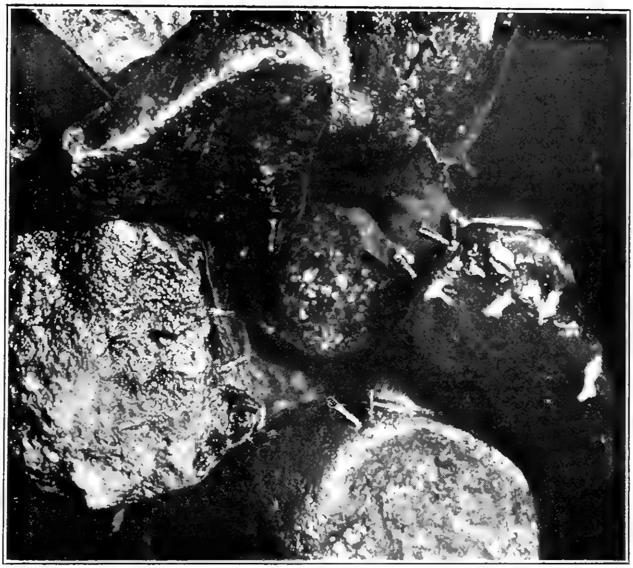

Fig. 126. "Picket" caddis-worms in their square cases, showing characteristic position and attachment. On wet boulders along the Lamar River. Photo July 25.

Fig. 127. Caddis-worms along the Lamar River, left stranded by recession of the stream. Two types are here shown,—"picket" caddis-worms (*Limnephilus*) and "barnacle" caddis-worms. Photo Aug. 8.

Fig. 128. "Cornucopia" caddis-worms in a cluster on a rock during pupation period. Lost Creek, July 19.

Fig. 129. A closer view of the same cluster of cornucopia caddis-worms shown in figure 128. Note the resemblance to pine needles.

are used extensively as food by the stone-flies and may-flies, and in this respect become as important, though indirectly so, as their enemies. Among strange and unusual foods can be listed the surface bait.

In general, fish are opportunists as far as their food is concerned. They eat what animal food is available, regardless of the origin. As a result, if one knows the animal life of a particular region, one can tell from the stomach contents where a fish has fed. In a lake, for instance, the plant and animal life is distributed in regular "zones," most animals limiting themselves to particular depths. Some are found only on the shores, others on the vegetation in the shallows, still others only in the muck at considerable depths. With a knowledge of the animals found in these various zones it is possible to learn a good deal about the food habits of a fish, his migrations, and his food preferences.

On the whole, fish are indiscriminate in their choice of food as far as quality is concerned. They like to feed in a particular region, and stay there until satiated. Thus, when feeding from plants, they eat whatever they can find there; and once they begin to feed from plants they continue feeding there until their hunger is satisfied. At periods of plentiful food, fish do not migrate while feeding.

Curious to say, it often happens that a fish may find a certain type of food so much to his liking that he will seek only that type. This may be worms, leeches, snails, back swimmers, caddis-worms, or other kinds. Thus, we may find stomachs filled with dozens of individuals of one type of animal, such as crayfish or snails. Even more striking, one may find stomachs filled with highly distinctive cases of some particular species of caddis-worm.

This predilection for some particular food is more often observed in the case of surface food than in water bait. I have found fish stomachs, including trout stomachs, gorged with hundreds of specimens of a single type, such as ants, grasshoppers, dragon flies, caddis-flies, orl flies, may-flies, midges, etc., indicating that the particular fish had taken a fancy to this special type of food, and had hunted assiduously for the delicacy. There is nothing abnormal in such a predilection, not more so than in the case of a boy who makes a meal off desserts, be it ice cream, or fruit, or cake. But right there, in the longing for the unusual, lies the weakness of the feeding habits of fish, the trait which lays them open to capture by the angler. Since the unusual attracts, anglers have made use of this phenomenon in the types of flies selected by them.

A fish is easily deceived, for he is not very observant. His eyesight is poor and he recognizes things chiefly through their movements. For instance, when an angler uses a fly, the fish is supposedly deceived by three factors,—form, pattern, and movement. In the matter of form and pattern the fish's vision is too weak and near-sighted to recognize the bait for what it is. He is used to certain distorted images which impress him more through motion than by any other factor, and he captures or tries to capture such a moving object. But it is also the unfamiliar, the unusual, which tempts fish, perhaps more than the customary objects. How else can one explain the presence of blocks of wood, of straws, twigs, leaves and the like, in fishes' stomachs? On more than a dozen occasions I have found blocks of wood in trout stomachs. In at least half the cases there was not the remotest resemblance in the shape of the block to any type of surface bait. An irregular cube has no resemblance to any insect, while an oblong bit might well have the approximate outline of a stone-fly or a grasshopper. But it was probably the strangeness, the unusualness of the block of wood which attracted and tempted the trout. The most interesting feature of these instances was that in only one case were the blocks of wood taken by a hungry fish; that is, only once were the blocks of wood the sole stomach content. In all other instances, blocks and sticks were gulped by fairly well-fed fish. One might say that they were taken as a sort of salad or dessert, indicating that their novelty tempted the fish.

The foregoing has its practical application. When fish are well fed they may rise to bait, but less to grasp it than to look it over. Every fisherman has seen some coveted fish rise thus, examine the bait, roll over lazily, and return to his retreat. However, if the bait be unusual, a fish may be led to bite if he is convinced that the lure offered is some particularly juicy morsel which should be a fitting wind-up to his meal. The more the bait offered resembles some moving surface bait, the more likely is the trout to strike at it.

As emphasized before, a fish is near-sighted, and even close up his vision is poor; he sees objects more or less distorted. On top of all this he is not particularly intelligent, but rather stupid. It takes him a long while to learn a simple fact, and hence he is easily deceived. If the fly because of its resemblance to a regular food item does not attract, try the unusual. This should be particularly effective when the fish has fed, or is partly satiated.

HINTS TO ANGLERS IN YELLOWSTONE PARK

Your Attitude.— In older days man hunted because he required food. Modern conditions have supplanted hunting by the domestic breeding of animals, so that a sufficient food supply is at hand. Moreover, agriculture has encroached on nature's fastnesses to an extent that these cannot possibly propagate a sufficient food supply in the natural state. The hunting instinct, engendered because of necessity for so many generations, must naturally be slow to die out. So man still loves to hunt, be it big game, fish — for fishing is but hunting in the water,— flowers, or little game, such as insects and still smaller things. For years hunters have realized that game is getting scarce, that it is more difficult to stalk, and that the cost of hunting is fast increasing. But because there is no longer any real necessity for hunting, it follows that our inherited attitude should be modified to conform to the new conditions. This change is already evidenced in the attitude of the conservationists, of the nature lovers, and of sportsmen.

What is a sportsman? The popular and correct idea of such a man is that he hunts for the pleasure of the hunt, for the thrills he receives in pitting his ingenuity against that of the quarry he seeks. He possesses discrimination; he does not kill wantonly, he does not slaughter, he is moderate in the amount of game he hunts. He is not cruel, but kills his catch at once and does not let it suffer needlessly. His bag is made up of choice specimens rather than of many; he seeks quality, not quantity. He will not countenance "mass killing," as in the case of dynamiting streams or even catching the legal limit when that is obviously too high. He is eminently a man who believes in the "square deal," for himself, for others, for the things he hunts. A splendid ideal, this synthetic conception of the sportsman! And he is not a phantasm, but a reality; he is made up of you and me, of the best that is in all of us.

Fishing is the one type of hunting that is still available to all of us, and the only kind that can possibly be allowed in our National Parks. Big game and wild life of all kinds are becoming more and more restricted to natural strongholds, some of them difficult to reach. But fish! They travel in the waters that pass our very doorsteps. Thus a source of both food and pleasure is easily avaliable. Fish as a reserve food supply are unfortunately too little esteemed. Few people, even well informed citizens, realize and appreciate the food resources of the waters in the United States. Generally, people fish with little thought of where the fish came from and whether more are to follow.

Yet even with all the tremendous resources of inland waters, game fishing, that is, for fish that battle fiercely with the angler, has gradually become restricted to the less accessible places. Trout fishing has always largely been confined to turbulent streams and mountain lakes. But how often does one hear the regretful exclamation: "Fished out!" The angler himself is to blame; not he individually, but his kind. There have been many fishermen, but too few sportsmen. In the wonderful trout streams all through the Rockies we see the same discouraging results. In the populated areas the streams are now fished out, while in distant but readily accessible regions the numbers and size of the fish have decidedly decreased. Throughout Idaho, for instance, the mountain streams in their lower reaches have been fished so thoroughly that a two-pounder trout has become a rarity. The old settlers tell of four- and five-pounders, even of eight-pounders, but the present generation does not know them. True, the streams are still plentifully restocked, chiefly through the efforts of the fish hatcheries; but what are the chances of a trout against thousands of anglers when each wants to catch his legal limit every day, regardless of whether he can use them all? No propagation, natural or artificial, be it ever so thorough, can keep pace when anglers catch at the rate of sixty to a hundred fish a day.

Just consider for a moment what it means to raise a trout under natural conditions! The eggs are laid in great numbers in shallow rapids, to be carried passively by the current. They become trapped in the interstices between the rocks and there go through their development. But before this the eggs may become the prey of larger fish; they may be crushed between rocks, or silted over; they may be carried by the flood water to some lateral pool, to dry up later with the pool or perish from lack of aeration; or they may become a prey to parasites or to a fungus (*Saprolegnia*) that attacks the eggs of almost any freshwater animal.

If the eggs survive, they hatch into fry that carry their food with them in a small yolk sac. When this stored food, received from the parent, is used up by the fry they hunt the shallows in quest of small insects, diatoms and other minute food. But here they are exposed to predacious insects and larger fish, to the action of molar agents, such as winds, waves and currents, all of which combine to render their life precarious. Parasites, too, lurk in the shallows. Everything considered, it is surprising that so many do survive. But it takes

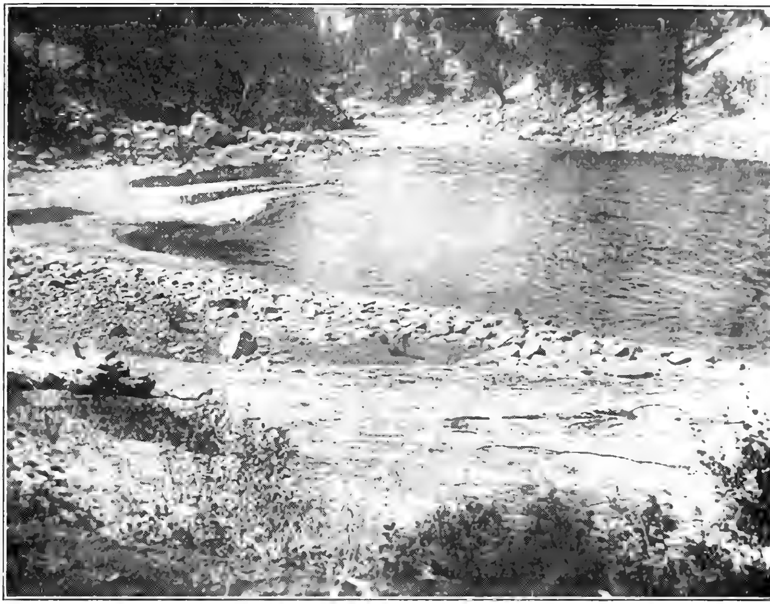

Fig. 130. An eddy of the Lamar River about 500 yards above its mouth. The shallow, pebbly pools at left are favorite feeding places for the young of trout, minnows and suckers. Photo July 16.

Fig. 131. Shore of the Lamar River about 150 yards above its mouth. The "holes" formed by the eroded rocks are favorite spots for adult trout. Photo July 22.

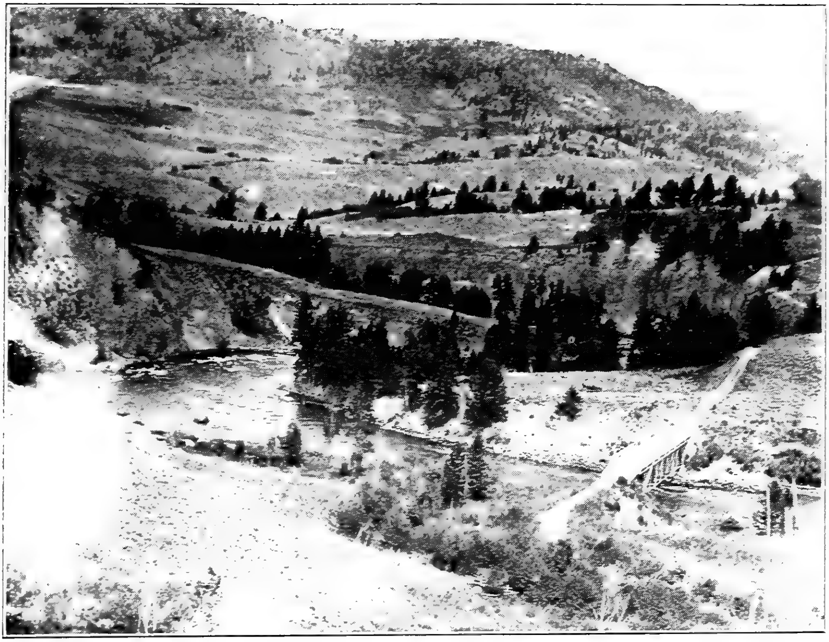

Fig. 132. Panoramic view above confluence of Yellowstone and Lamar Rivers. Cooke City Road and bridge across the Yellowstone, at right; Lamar River valley in middle distance. Photo Aug. 8.

Fig. 133. Junction of the Yellowstone and Lamar Rivers at low water stage. View downstream: Yellowstone River at left, Lamar entering at right. In the spring the boulders in the foreground are under water. Photo Sept. 5.

several years for trout to attain a good size and weight, and the angler should appreciate that it is the excessive toll he exacts that prevents fish from reaching a real " fighting " size.

Trout of large size are happily still available in Yellowstone Park. One- or two-pounders are quite abundant in the streams, while larger fish, of four and even five pounds, hide in the more inaccessible " holes " of the Yellowstone, Lamar and other rivers. But these last are only for the truly elect — the sportsmen who will take risks and pains for the opportunity to match their skill and wits against those of the wary trout. Figures 131 to 133 show some of the favorite trouting haunts in the delightful Camp Roosevelt region where this particular study was made.

Fishing in the Park is a pleasure that appeals to many of us. But if that pleasure is to continue in this " nation's playground," it must be limited for each of us so as to be shared by the many. Unrestricted fishing — " butchery " would be the more applicable word — is destructive no matter where it occurs. To preserve the opportunities of the Park — indeed, of every natural resource, there and elsewhere — there is needed the support of every public spirited citizen. Fishing is a splendid sport, one that should remain to us in the future as well as now. Truly, then, what fishing we do should be in the spirit of fair play, of moderation, of consideration for others,—this is the attitude of the true sportsman.

How to Fish.— The following points may be of use to amateur fishermen. They are based on the conditions noted in the first part of this discussion:

1. Stand low on the shore and cast your line far out, holding the rod low.

2. Keep moving. If the fish do not rise after a few casts, move to another spot. As a rule you cannot sit still and fish successfully for trout, as one does for perch or herring. Trout are not quite so stupid as most other fish; they cannot afford to be.

3. Let your fly strike the water sharply and quickly; do not dangle your bait. Trout cannot be treated like perch. They do not " nibble "; they make up their minds and strike quickly, or not at all.

4. When the fish is hooked, play him with a steady line. Take up the slack; but above all, do not jerk. The steady pull does the trick.

5. Pull the fish well up to the shore before you ease the line, Otherwise, he may manage to slip the hook and get away.

6. Should you enter the stream, see that your shadow does not lie with the current.

Bait and Flies.— Many interesting things may be learned about the habits of fishes by a little careful study of natural and artificial lures.

1. Note whether insects are being carried by the stream. Try to see what insects are abundant on the shore and use some of these for bait.

2. When hooking an insect, hook it in the axis of the body through the *top* of the thorax. The hook should enter behind the thorax and come out in front behind the head. In this way the destruction of the insect's brain and nervous system is avoided and the bait will struggle when striking the water,— hence an additional element to deceive the fish. Do not pierce the head, or hook through the under side; for the brain of an insect lies near the top of the head and two connections go to the nerve cord, which lies in the thorax and abdomen, on the "belly" or ventral side. If you hook the brain or cord, death or paralysis will result and the bait will not be so attractive. Hooking through the thorax is best, because that part of an insect is firmest, since its strong plates are needed for the attachment of the leg and wing muscles.

3. When you have caught your first fish, kill it by striking it sharply on the front of the head, or by thrusting a knife blade through the neck to sever the spinal cord. Examine the stomach contents and note whether it comprises a general mixture or if some particular insect is more abundant. Then select that type for bait. Or if you prefer an artificial fly, try one which seems to bear some resemblance to the bait eaten.

4. A hungry fish will accept almost anything in the line of bait. After mid-forenoon, however, greater care must be used in choosing baits or flies.

5. A satiated fish will refuse the regular diet, but, like human beings, he does not despise something choice in the way of dessert. Some lure that seems strange and looks palatable may often entice a surfeited fish to bite.

6. When you have caught sufficient fish for a meal, and are still keen for the sport, try for some situation that requires special skill. Try for some old Methuselah and see if you can outwit him. Since he is too wise to be lured by ordinary methods, you may have to resort to unusual tactics. All animals, like men, have their trait of curiosity, and an old and wary trout is not exempt. In such cases, do not make your approach too obvious. Bait or flies that appear easy to capture will not tempt him. Try an unusual bait, and make it require some effort on the part of Methuselah to get it.

Your Catch.— The following suggestions are important for beginners in the gentle art of angling:

1. It is not necessary to catch the legal limit to prove yourself a good fisherman. The true sportsman looks for quality, not quantity. Quantity does not necessarily indicate skill,— only some luck, and greed.

2. Kill your fish as soon as you have caught him, and before cleaning. There is no need of causing useless suffering. The habit of cruelty to animals engenders the habit of cruelty to men.

3. If your trout is below legal size, carefully disengage it under water, taking care not to rub off the slime which is the protective covering of the fish.

4. Do not allow your catch to lie in the heat of the sun, or decomposition will set in. Clean and pack the fish before returning to camp, burying the offal so as to leave no disagreeable traces for those who follow you.

5. When packing trout to take back to camp, wrap each one separately in coarse grass and see that they lie compactly so that they will not jolt. If loose, even slight movements of your body will jar and bruise them, and they will speedily become soft and unappetizing.

6. Weigh and photograph your trout; and possibly you may also wish to write a permanent record of your fishing adventure. In retrospect, this frequently proves to be the most satisfying part of one's catch.

THE FIELD-NATURALIST'S WORK

The average field-naturalist tends to become a collector of specimens rather than an investigator of the ways of animal life. His ambition is to collect the specimens as soon as he can, and as many as he can; and fearing lest each specimen shall escape him and be lost, he neglects the opportunity to observe it in life and to learn something about its habits and its ways. Often he takes this attitude from the institution for which he is working. It desires a great series of specimens which he feels he must secure. Yet the collecting of a large series of specimens, and the bringing them home in satisfactory shape, should be only a small portion of the field-naturalist's work. Skins and skulls are useful, but skins and skulls and measurements and proportions tell us only a little about the living animal. Most of us wish to learn something about its ways of life.

George Bird Grinnell.
Foreword, Roosevelt Wild Life Bulletin,
Vol. 1, No. 1, p. 9; 1921.

CURRENT STATION NOTES

THE NATIONAL OUTDOOR RECREATION CONFERENCE

The pioneer spirit of Americans and their love of the outdoor life has given us an interest and a tradition which has been of the greatest National importance. To foster this spirit and to encourage intelligent coordinated leadership in these matters was evidently the primary aim of President Coolidge's Outdoor Recreation Conference. The field is so vast and the number of organizations concerned so great that it is almost impossible to keep abreast with the movement. To facilitate the interchange of ideas, to formulate broad general policies, and to develop harmonious relations was thus the logical need championed by the President. The Conference met at Washington May 22, 23 and 24, 1924, and was composed of delegates representing 128 organizations.

The Conference was a great success and the President and his associates are to be congratulated most heartily indeed for its outcome. The Executive Chairman, Col. Theodore Roosevelt, handled the situation admirably and was ably assisted by Mr. Charles Sheldon, a Washington sportsman-naturalist, who seems to have been a moving spirit in initiating this good work.

Eighteen committees were in session, covering important aspects of the field, including fish, game and fur-bearing animals, birds, parks, forests, pollution, lands, and other topics. These committees were called upon to summarize present conditions, and to present constructive recommendations.

The outcome of the Conference is a permanent Advisory Council of 100, which will cooperate with the President's Committee.

Some of the outstanding resolutions deserve mention. One supported the ideal that our National Parks must be completely protected from economic use, and preserved in a "condition of unmodified nature." The National Forests are set aside for permanent forest uses on the non-agricultural land, including recreation, and attention was called to the fact that the U. S. Forest Service is particularly qualified to administer the wild life of these forests. The importance was stressed of the basic need for surveys and inventories as a means of determining bag limits of birds, and the need of sanctuaries in connection with all public shooting grounds. Special emphasis was given to the need of non-political State game commissioners, of trained staffs, long tenure, and broad administrative powers; that campaigns for the extermination of predatory animals be discouraged except as authorized by State and Federal experts; that all sportsmen should cooperate with scientific institutions to make the results of their hunting available for study and record; that the annual volume of game killing should be reduced by the shortening of the open season, and by the reduction of bag limits "by large amounts where necessary"; that for a sound basis for the administration of fishery resources scientific investigations are needed; and that Federal legislation should prevent interstate shipment of black bass. The menace of water pollution was stressed from the standpoint of recreation and fish culture, as well as the indiscriminate drainage of lands, without careful preliminary study of the situation in each case.

Not since President Roosevelt called the National Conservation meetings at Washington has public attention been directed to the vital need of a sane policy toward these resources. Furthermore, the social or welfare aspect of conservation was not so clearly expressed then as at this Conference. In those earlier conferences the economic aim was dominant, but at this Conference the welfare aspect was in the foreground. An important step has been taken and it deserves the support of everyone.

THE ROOSEVELT WILD LIFE STATION AND THE CONFERENCE ON OUTDOOR RECREATION

The Roosevelt Station was well represented by several of its members at President Coolidge's Conference. The Executive Chairman was the Honorable Theodore Roosevelt; Mr. Chauncey J. Hamlin was Chairman of the Committee to effect Permanent Organization, and Dr. George Shiras, 3rd, was a member of the same Committee. Dr. Frank M. Chapman was a member of the Committee on Birds. These are all members of the Honorary Advisory Council of the Wild Life Station. Dean Franklin Moon was a member of the Central Resolutions Committee, and the Director of the Station was a member of the Committee on Birds. Dr. Hugh P. Baker, former Dean of the College during the period in which the Roosevelt Station was established, was a member of the Committee on Survey and Classification of Recreation Resources. The Director was the official representative for the Wild Life Station, and also a delegate for the Ecological Society of America and the American Society of Mammalogists.

Papers or addresses were read at the Washington Conference by Hon. Theodore Roosevelt, Dr. Frank M. Chapman, Dean Franklin Moon, Mr. Chauncey J. Hamlin, and the Director of this Station.

In the Permanent Organization, which was an outgrowth of the President's Conference, the following Station members are included on the President's Committee: Hon. Theodore Roosevelt, and Mr. Chauncey J. Hamlin, Chairman of the Conference. Mr. Hamlin is also a member of the Executive Committee, as is also Dr. George Shiras, 3rd. Other members of the Advisory Council of the Conference are Dr. Frank M. Chapman, Dean Henry S. Graves, Dr. George Bird Grinnell, Mr. Chauncey J. Hamlin, Dr. George Shiras, 3rd, and Dean Franklin Moon.

THE SUMMER FIELD PARTIES

During the past summer field season (1924) the Roosevelt Station field parties have been engaged in investigations on wild life in New York State. Dr. Charles E. Johnson, who made the earlier survey of the Adirondack beaver (*Roosevelt Wild Life Bulletin* Vol. 1, No. 2), has continued this study, making a complete circuit of the region. Mr. Bradford A. Scudder devoted the season to a preliminary study of the status of Adirondack deer. This seems to be the first study of this character to be undertaken. These men were assisted by an able volunteer assistant, Mr. Julius M. Johnson. Dr. Alfred O. Gross has devoted his attention to an intensive study of the Ruffed Grouse in the lower Hudson Valley. Reports are now in preparation on the results of these studies. Dr. W. C. Kendall and Mr. W. A. Dence extended their studies of Adirondack trout.

The Director of the Station spent July, August and September visiting the National Forests and National Parks of the Southwest and on the Pacific Coast. He visited the District Forest offices at Albuquerque, San Francisco, Ogden and Denver, as well as the Southwestern Forest Experiment Station, the Great Basin Range Experiment Station, and the Fremont Forest Experiment Station. Special attention was given to seeing as much of field conditions as time permitted, with particular reference to wild life, research, grazing, recreation, and general Forest and National Park policies.

The National Forests visited were Carson, Coconino, Tusayan, Kaibab, Sequoia, Stanislaus, Sierra, Wasatch, Manti, and Fremont, and the National Parks were the Grand Canyon, Sequoia, and the

Yosemite. With regard to the Forests he was particularly impressed with the serious and widespread over-grazing, with few exceptions the relative paucity of game, and with the keen appreciation on the part of local forest officials of the importance of game and of forest recreation in its relation to securing public support for general forestry purposes. He was pleased to note the widespread recognition of the severe menace of over-grazing. The urgency of greater financial support for silvicultural research was very evident, and the need of extending research to other fields of forestry than silviculture and grazing was equally evident. Several serious administrative difficulties have arisen because of this lack of adequate research and publication regarding wild life and other problems. The enthusiasm and devotion of the Forest and Park officials was a very encouraging feature. The relatively rapid increase in the number of Park Naturalists, shows a growing appreciation of the importance of this aspect of Park work.

THE ROOSEVELT WILD LIFE MEMORIAL

As a State Memorial

The State of New York is the trustee of this wild life Memorial to Theodore Roosevelt. The New York State College of Forestry at Syracuse is a State institution supported solely by State funds, and the Roosevelt Wild Life Forest Experiment Station is a part of this institution. The Trustees are State officials. A legislative mandate instructed them as follows:

"To establish and conduct an experimental station to be known as 'Roosevelt Wild Life Forest Experiment Station,' in which there shall be maintained records of the results of the experiments and investigations made and research work accomplished; also a library of works, publications, papers and data having to do with wild life, together with means for practical illustration and demonstration, which library shall, at all reasonable hours, be open to the public." [Laws of New York, chapter 536. Became a law May 10, 1919.]

As a General Memorial

While this Memorial Station was founded by New York State, its functions are not limited solely to the State. The Trustees are further authorized to cooperate with other agencies, so that the work is by no means limited to the boundaries of the State or by State funds. Provision for this has been made by the law as follows:

"To enter into any contract necessary or appropriate for carrying out any of the purposes or objects of the College, including such as shall involve cooperation with any person, corporation or association or any department of the government of the State of New York or of the United States in laboratory, experimental, investigative or research work, and the acceptance from such person, corporation, association, or department of the State or Federal government of gifts or contributions of money, expert service, labor, materials, apparatus, appliances or other property in connection therewith." [Laws of New York, chapter 42. Became a law March 7, 1918.]

By these laws the Empire State has made provision to conduct forest wild life research upon a comprehensive basis, and on a plan as broad as that approved by Theodore Roosevelt himself.

Form of Bequest to the Roosevelt Wild Life Memorial

I hereby give and bequeath to the Roosevelt Wild Life Forest Experiment Station of The New York State College of Forestry at Syracuse, for wild life research, library, and for publication, the sum of ...., or the following books, lands, etc.

[Syrac]use Univ. Bull., Vol. 23 October, 1923 - 25 Number 3

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BIG GAME ANIMALS OF THE YELLOWSTONE.

FOOD OF THE YELLOWSTONE TROUT.

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ROOSEVELT WILD LIFE BULLETIN, Vol. 2, No. 4. February, 1925.

1. The Relation of Wild Life to the Public in National and State Parks. Dr. Charles C. Adams.
2. The Big Game Animals of Yellowstone National Park............. Mr. Edmund Heller.
3. The Food of Trout in Yellowstone National Park................. Dr. Richard A. Muttkowski.
4. Current Station Notes...................The Director and Editor.

ROOSEVELT WILD LIFE BULLETIN, Vol. 3, No. 1. February, 1925.

1. The Birds of the Yellowstone National Park.....Milton P. Skinner.
2. Current Station Notes....................The Director and Editor.